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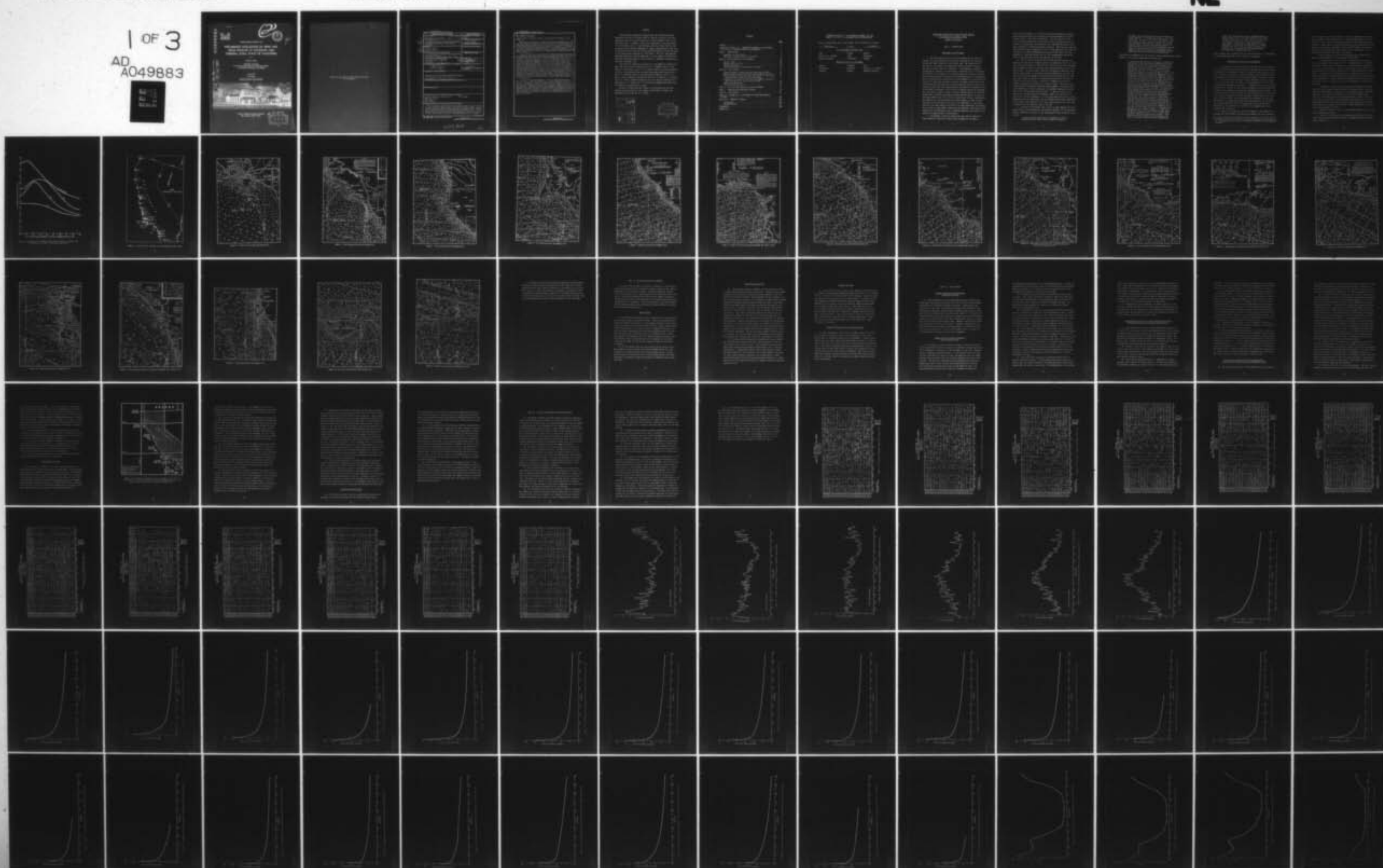

MISCELLANEOUS PAPER H-78-2

PRELIMINARY EVALUATION OF WIND AND WAVE EFFECTS AT POTENTIAL LNG TERMINAL SITES, STATE OF CALIFORNIA

by

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January 1978

Final Report

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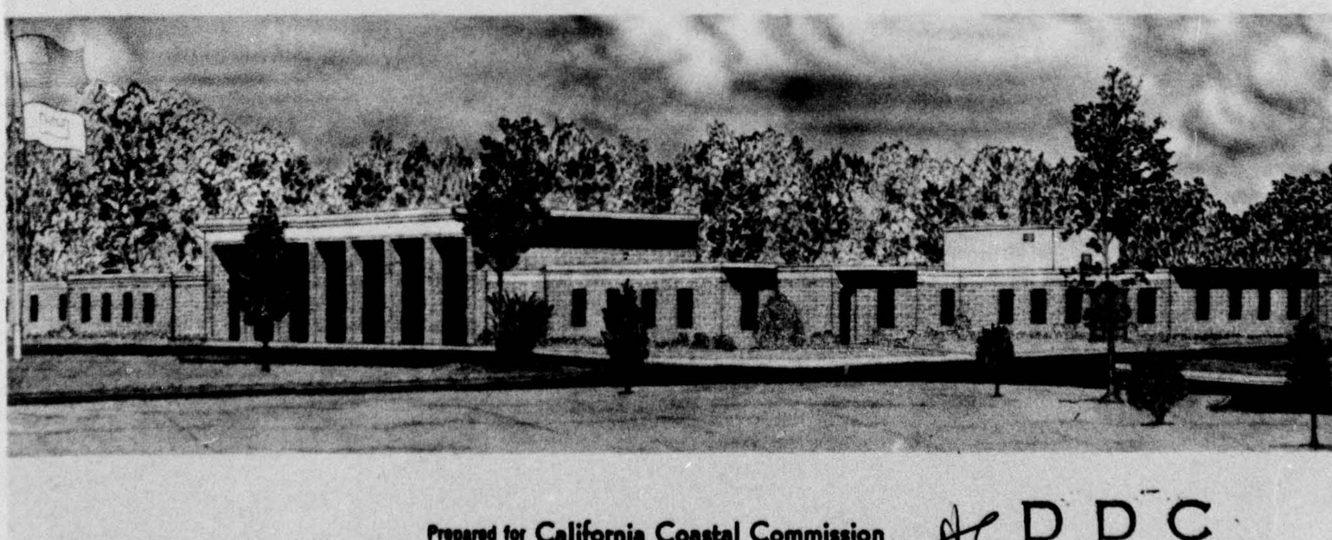

Prepared for California Coastal Commission
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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The California Legislature decreed that the California Coastal Commission had until 1 February 1978 to identify, evaluate, and rank alternate potential Liquefied Natural Gas (LNG) Terminal sites on the California coast. Because of the Corps' experience in various aspects of such studies, the U. S. Army Engineer Waterways Experiment Station was requested by the Coastal Commission to assist, particularly in the use of existing hindcast data to evaluate

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20. ABSTRACT (Continued)

possible effects of wind and waves on the docking and unloading of a LNG tanker.

The effect of wind and wave climate was relatively evaluated at 26 potential LNG terminal sites along the coast of California. The analysis did not apply wave refraction theory at any of the sites, so the absolute magnitudes of the values obtained at each site are subject to refinement. The computations which were performed were optimized on a site-specific basis; i.e., they have been determined by utilizing the situations unique to that one particular location, and the results should not be extrapolated far beyond the respective site, if at all.

It was concluded that in the absence of breakwater protection and using the assumptions under which this study was conducted, the sites south of Point Conception will, in general, have a higher percentage of operating time than locations to the north. That is not to say, however, that a northern site could not be selected, adequately protected, and effectively used. Wind and sea conditions are not independent, because the occurrence of high seas is usually accompanied by high winds. Hence, downtime caused by high waves should not be merely added to downtime caused by excessive winds. Probably a fairly good first approximation would be to take the larger of the downtimes caused by optimized wave or wind conditions and add to this the supplemental downtime caused by northern or southern swell. Of all the sites investigated, sea conditions accounted for 65 percent of the optimized downtime, northern hemisphere swell accounted for 22 percent, and southern hemisphere swell was responsible for around 13 percent, on the average. Of course, some sites were geographically oriented so that they did not receive any southern swell and others did not receive any northern swell. One site, WES 11a, is exposed only to sea conditions.

In order to refine the downtime at a site, the best available wave climate for that site should be ascertained. To improve the wave climate estimate, it is necessary to refract the deepwater hindcast data to the LNG site and obtain the refracted and shoaled wave condition. Generalized discussions are insufficient inasmuch as the localized topography entirely influences the resulting wave regime, and the effects are different for different periods and different directions of approach. The wave field is the primary input variable in any type of wave action study; and it is imperative that the statistics be as correct as possible in order that the decision-making process be based on valid data.

PREFACE

The California Legislature decreed that the California Coastal Commission had until 1 February 1978 to identify, evaluate, and rank alternate potential Liquefied Natural Gas (LNG) Terminal sites on the California coast. Because of the Corps' experience in various aspects of such studies, the U. S. Army Engineer Division, South Pacific, was requested by the Coastal Commission to assist, particularly in the use of existing hindcast data to evaluate possible effects of wind and waves on the docking and unloading of a LNG tanker. The U. S. Army Engineer Waterways Experiment Station (WES) was, in turn, asked to provide the technical assistance required by the request. Authority to proceed was received 1 December 1977.

The study was conducted by personnel of the Hydraulics Laboratory, WES, under the general direction of Mr. H. B. Simmons, Chief of the Hydraulics Laboratory, and Dr. R. W. Whalin, Chief of the Wave Dynamics Division. Data analysis was conducted under the direct supervision of Mr. D. D. Davidson, Chief of the Wave Research Branch, and Dr. L. Z. Hales, Project Engineer, assisted by Messrs. R. D. Carver, D. G. Markle, and C. R. Curren, Research Engineers, Ms. R. M. Brooks, Mathematician, and Messrs. L. A. Barnes and C. R. Herrington, Engineering Technicians. The report was prepared by Dr. Hales.

Director of WES during the conduct of this study and the preparation and publication of this report was COL John D. Cannon, CE. Technical Director was Mr. F. R. Brown.

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CONVERSION FACTORS, U. S. CUSTOMARY TO METRIC (SI) AND METRIC (SI) TO U. S. CUSTOMARY UNITS OF MEASUREMENTS

Units of measurement used in this report can be converted as follows:

Multiply	By	To Obtain
U. S. Customary to Metric (SI)		
feet	0.3048	metres
miles (U. S. statute)	1.852	kilometres
degrees (angular)	0.01745329	radians
Metres (SI) to U. S. Customary		
metres	3.280839	feet
kilometres	0.6213711	miles (U. S. statute)
radians	57.29578	degrees (angular)

PRELIMINARY EVALUATION OF WIND AND WAVE EFFECTS AT POTENTIAL LNG TERMINAL SITES, STATE OF CALIFORNIA

PART I: INTRODUCTION

Statement of the Problem

1. The California Coastal Act of 1976 authorized, but did not provide for the determination of the exact location of one liquefied natural gas (LNG) terminal in the coastal zone. The Legislature of the State of California investigated the general problem of energy allocation to that state and found that: (a) an adequate supply of natural gas is essential to the economy of California and to the health and welfare of its residents; (b) the importation of liquefied natural gas from south Alaska and Indonesia into California may be a significant means of assuring that adequate and reliable supplies of natural gas are obtained in sufficient quantities to meet the state's needs and to prevent natural gas shortages which would disrupt the state's economy, increase air pollution, and impose personal and financial hardships on all of the state's residents; (c) an initial liquefied natural gas terminal may currently be needed in order to permit the importation of sufficient natural gas to prevent shortages which have been predicted to occur in the early 1980's; and (d) in order to expedite the siting, construction, and operation of such liquefied natural gas terminal so that serious shortages of natural gas do not occur, it is necessary to vest exclusively in one state agency (the Public Utilities Commission) the authority to issue a single permit authorizing the location, construction, and operation of such terminal, and to establish specific time limits for a decision on applications for such permit.

2. Accordingly, California Senate Bill No. 1081 to amend the Public Resources Code and to add certain sections to the Public

Utilities Code relating to a liquefied natural gas terminal, making an appropriation therefor, and declaring the urgency thereof, was passed 19 April 1977 to take effect immediately. The bill granted to the Public Utilities Commission the exclusive power to issue a permit concerning the construction and operation of a liquefied natural gas terminal pursuant to a prescribed permit procedure. The bill also required the California Coastal Commission (CCC) to study potential sites for the terminal and to make recommendations thereon to the Public Utilities Commission. California Senate Bill No. 1081 became known and may be cited as the Liquefied Natural Gas Terminal Act of 1977.

3. The Act further provided that in order for the Coastal Commission to carry out its responsibilities as required by the Act in the most expeditious manner, on the effective date of the Act the Commission should commence a study to identify and evaluate potential sites for an LNG terminal. Not later than 31 May 1977 the Coastal Commission shall complete and transmit to the Public Utilities Commission its final report evaluating and ranking the sites pursuant to Senate Bill No. 1081. Such report shall be deemed a recommendation to the Public Utilities Commission and shall include a transcript of hearings held by the Coastal Commission and a copy of all relevant files. Not later than 1 February 1978 the Coastal Commission shall submit to the Public Utilities Commission a report containing a preliminary ranking and evaluation of the terminal sites being studied. It was the intent of the Legislature in requiring this preliminary report to assure notice to the Public Utilities Commission of sites being considered by the Coastal Commission and that such report not be binding on the Coastal Commission in any respect for purposes of the final report required not later than 12 months after the effective date of the Act.

4. By letter of 9 November 1977, the U. S. Army Engineer Division, South Pacific, was requested by the Executive Director of the California Coastal Commission to assist in the evaluation of these potential sites, to wit:

> "...The California Legislature has given the Coastal Commission a very short time in which to identify,

evaluate, and rank alternate sites on the coast for an LNG terminal. A preliminary report is due 1 February 1978. Because of the Corps' experience in various aspects of such studies, we would like to ask your assistance particularly in the use of existing hindcast data to evaluate the possible effects of wind and waves on the docking and unloading of an LNG tanker at different sites...The key factor is the length of time an LNG terminal's operations might be interrupted by severe wind and wave conditions..."

Subsequent correspondence to the Division from the LNG Offshore Project Manager of the Coastal Commission indicated that:

"...Our executive director is writing to request the assistance of the Army Corps of Engineers in determining the effect of wave climate on operations at potential offshore and onshore sites for liquefied natural gas terminals along the California coast. The LNG Terminal Act of 1977 requires the Coastal Commission to prepare a report by May 31, 1978, evaluating and ranking alternative LNG terminal sites. A preliminary report is required by February 1, 1978... If the Corps is willing to provide this assistance... using existing hindcast data to evaluate the possible effects of the wave climate on the mooring and unloading of an LNG vessel along the California Coast. Due to our short deadlines we would like to suggest the following preliminary assumptions...(1) We need a draft report about January 15, 1978. (2) The report should identify the percent of time of a statistically average year that berthing or unloading operations would be interrupted by wave conditions together with the probabilities of interruptions lasting one, two, three, and four or more days. This shutdown percentage should be by month for the optimum orientation of a mooring on the windward side of a fixed facility...(3) Mooring depth would be a minimum of 50 feet below mean lower low water; sites of interest will generally be between the 50 foot and 600 foot depth contours off the California mainland and the offshore islands. (4) Man made breakwaters will not be considered at this state, but may be considered later. (5) At least three different hindcast studies might be used. These include the DNOD deepwater wave statistics, the Corps of Engineers' National Marine Consultants

> Report, and the NOAA/EDS Synoptic Shipboard Meteorological Observations...We would appreciate the opportunity to meet with the Corps' experts in this field to refine the study plan. After evaluating the final report, the Commission may request the Corps assistance on evaluating the feasibility of design alternatives such as the orientation of piers, the possible use of breakwaters, and the performance of single-point mooring facilities..."

These requests were transmitted by the Division to the U. S. Army Engineer Waterways Experiment Station (WES) for servicing.

Evaluation Criteria and Site Locations

5. At a meeting between personnel of WES and CCC in late November 1977, a detailed study plan was formulated and evaluation criteria were established for a systematic ranking of selected sites along the entire reach of California coastline from the Oregon to the Mexican border including specific locations on the offshore islands of southern California. It was decided that WES would compare the three existing sources of wave data (DNOD, NMC, and SSMO) at the DNOD deepwater station locations (monthly and yearly statistics). WES would then select the source judged best for conduct of this study and proceed to provide statistics at various sites based on the data base deemed to be most accurate. All statistics would be computed along the 60-ft* MLLW contour. These statistics would be made at locations shoreward of the deepwater stations plus locations WES felt were topographically influenced by coastline sheltering (i.e., Santa Cruz, Santa Rosa, Monterey Bay, and the shore of southern California from Point Conception to the International border) plus those locations at specific sites requested by CCC as potential LNG terminals.

6. While it is known that refraction effects of the offshore topography may significantly influence wave heights, the time constraint

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* A table of factors for converting metric (SI) units of measurement to U. S. customary units, and U. S. customary to metric (SI) is presented on page 3.

for this study and the large number of locations used made it impractical (in terms of both time and cost) to include refraction in the computation. Thus, while all computations have been performed consistent relative to each other, the absolute magnitude of the down-time may vary when the site-specific topographic effects are included. The effect of shoaling on wave height at a water depth of 60 ft is included in all computations; however, this effect is minimal.

7. The evaluation criteria for determining the availability of each site were decided to be promulgated in two forms:

(1) Terminals will not be usable if winds exceed 25 knots, or if H_s is greater than or equal to 6 ft. Histograms will be provided on percent downtime for wind speeds up to 50 knots and wave heights up to 12 ft. In this manner an estimate can be made of the sensitivity of the downtime to the criteria specified of 6 ft wave heights and 25 knot winds. In addition to the histograms based on annual conditions, all values exceeding 6 ft heights and 25 knot wind speeds will be determined on a monthly basis. The wind data will be taken from the SSMO wind observations. The 6 ft heights and 25 knot wind speeds are independent of direction.

(2) Another criteria for interruption of unloading operations will be the ship response curves obtained from model tanker tests performed by Delft Hydraulic Laboratories for the Oxnard marine terminal, June 1975. These data are optimization curves of acceptable wave heights for different period waves approaching the terminal which vary in direction from parallel to perpendicular with the mooring. Thus a requirement for the use of these cirteria is an evaluation of the optimum heading of the terminal at each site. These optimization criteria curves are presented in Figure 1.

8. The draft report for the 15 January 1978 deadline will not consider multiple wave trains.

9. Specific sites selected for evaluation according to the above criteria are located generally in Figure 2, and more precisely in Figures 3 through 19.

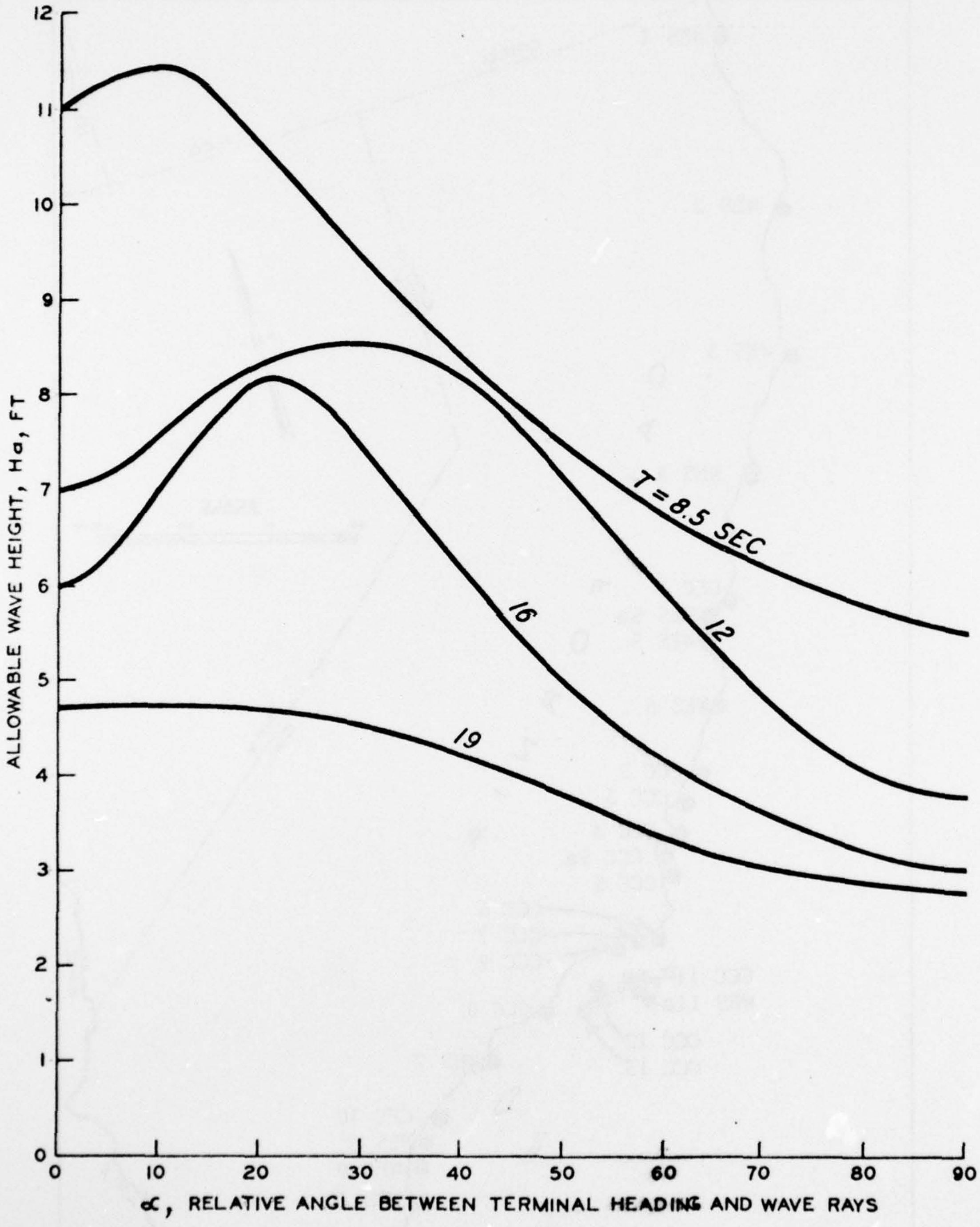


Figure 1. Allowable wave heights optimization criteria, windward side of terminal (after Delft Hydraulics Laboratory)

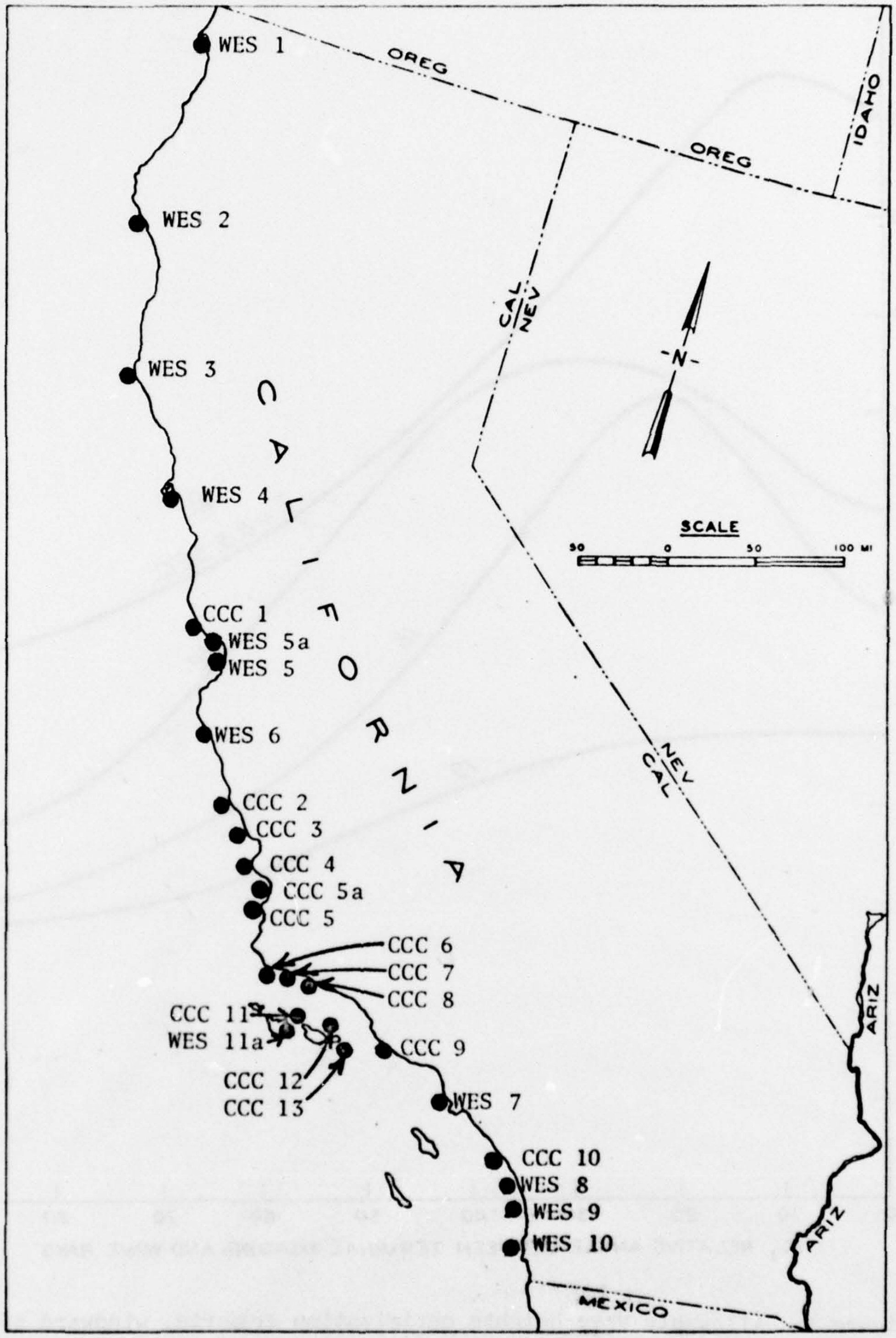


Figure 2. Potential LNG teminal sites evaluated in this study

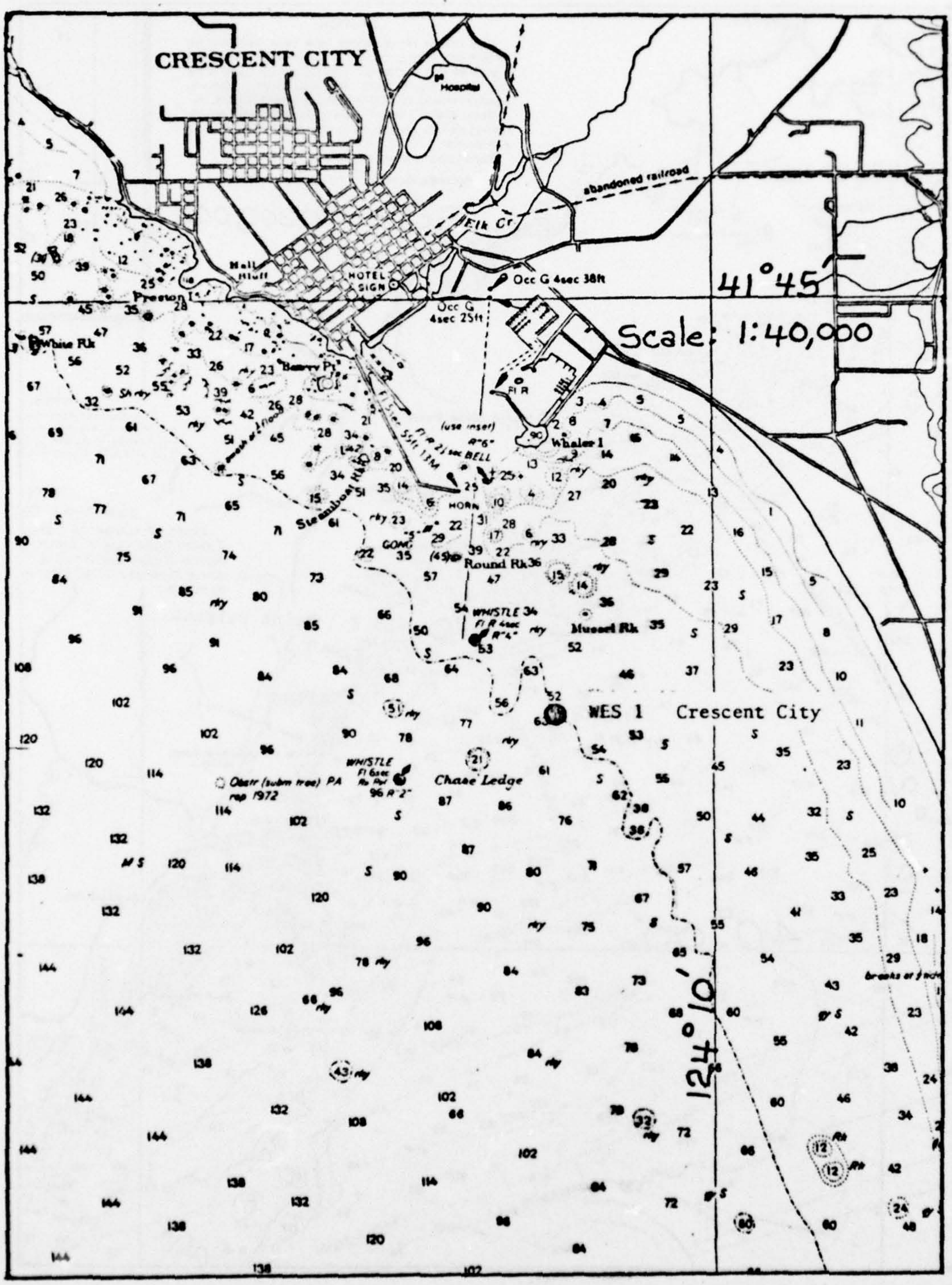


Figure 3. Crescent City potential LNG terminal site

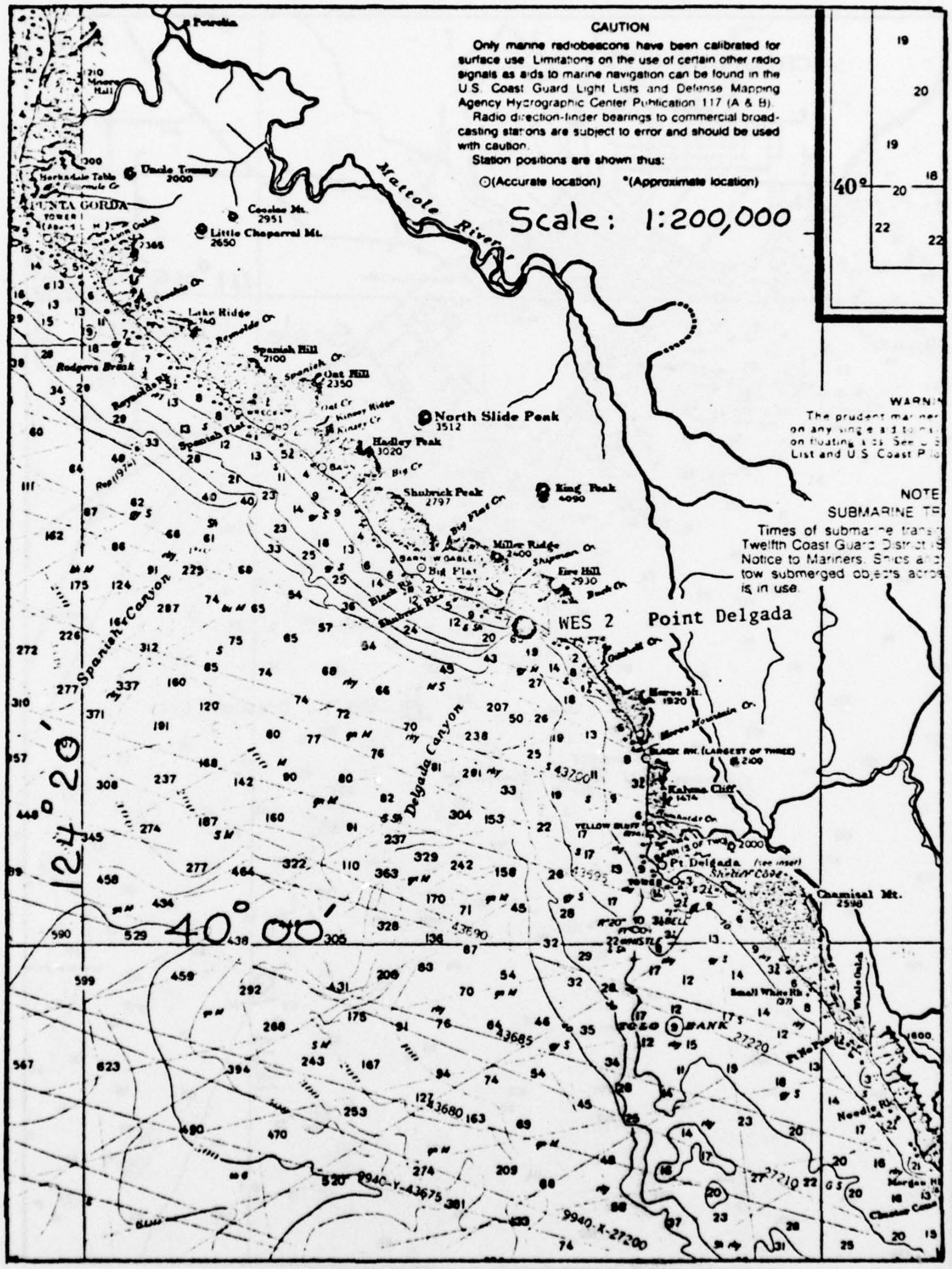


Figure 4. Point Delgada potential LNG terminal site

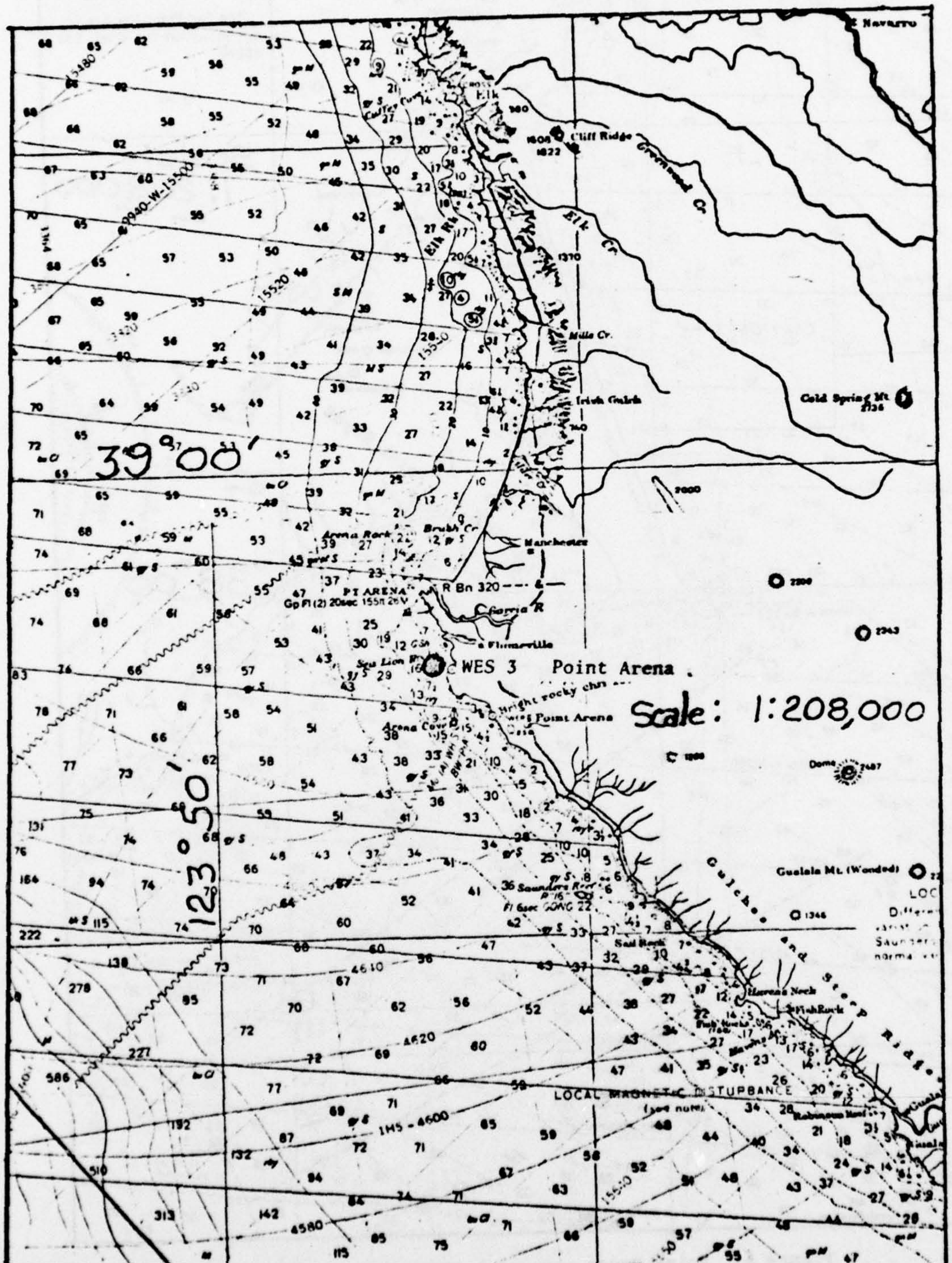


Figure 5. Point Arena potential LNG terminal site

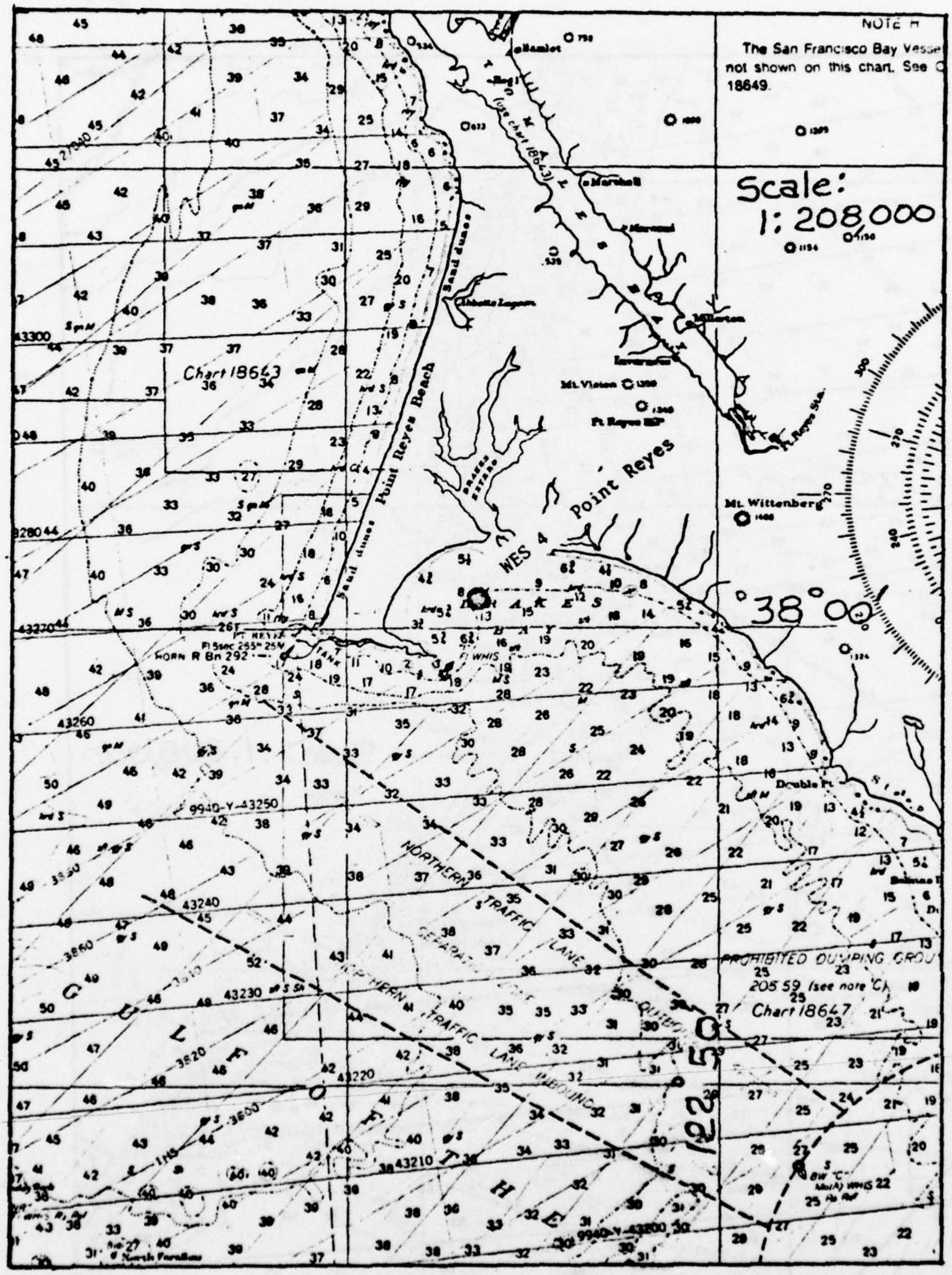


Figure 6. Point Reyes potential LNG terminal site

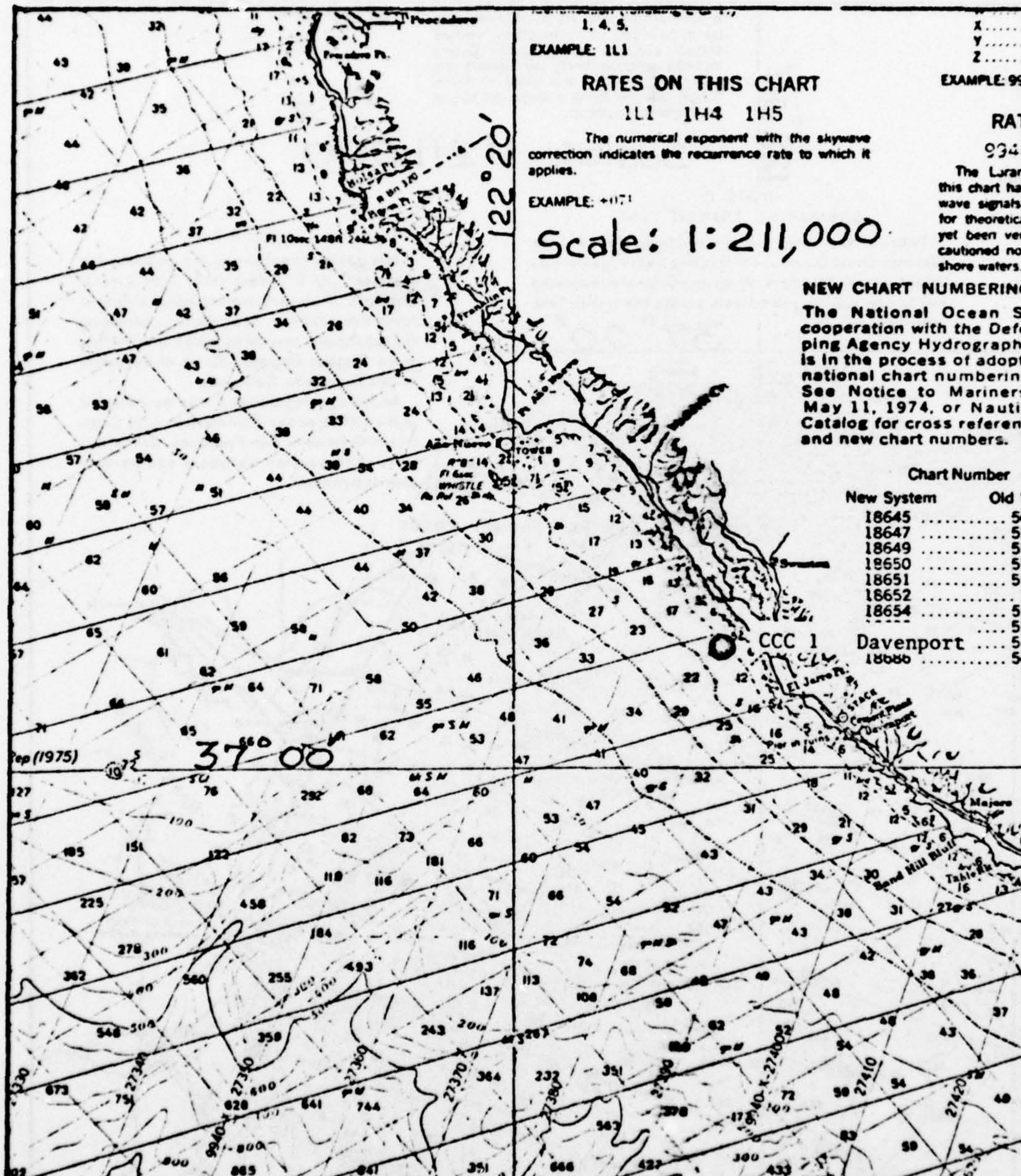


Figure 7. Davenport potential LNG terminal site

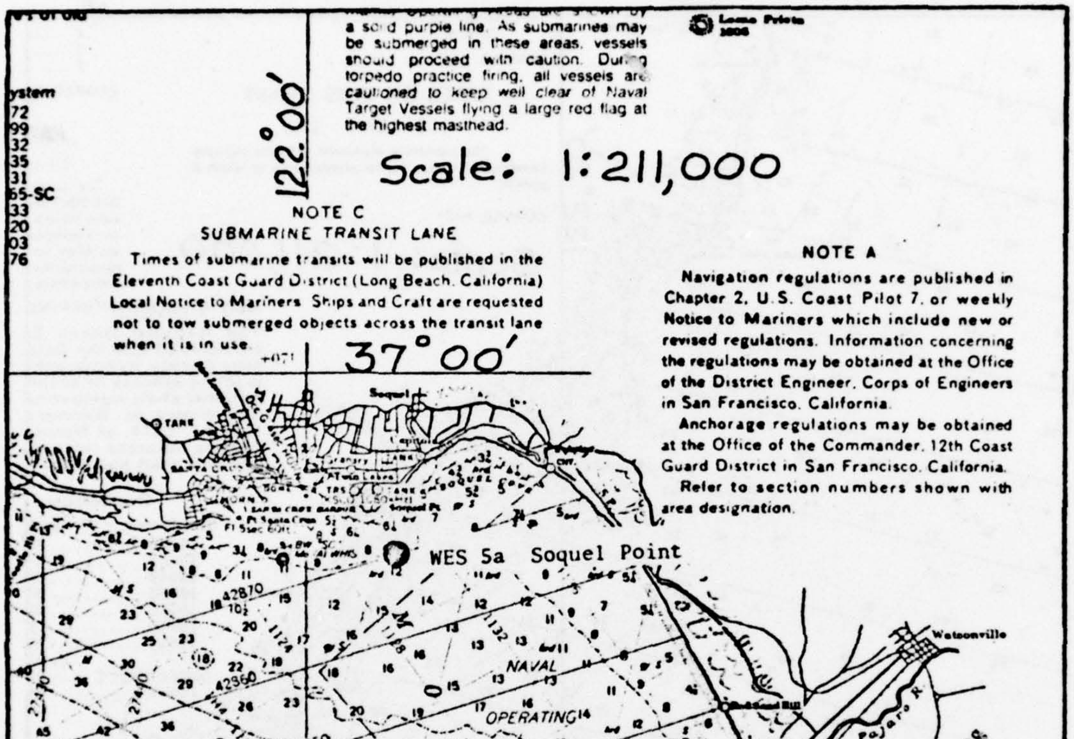


Figure 8. Soquel Point and Moss Landing potential LNG terminal sites

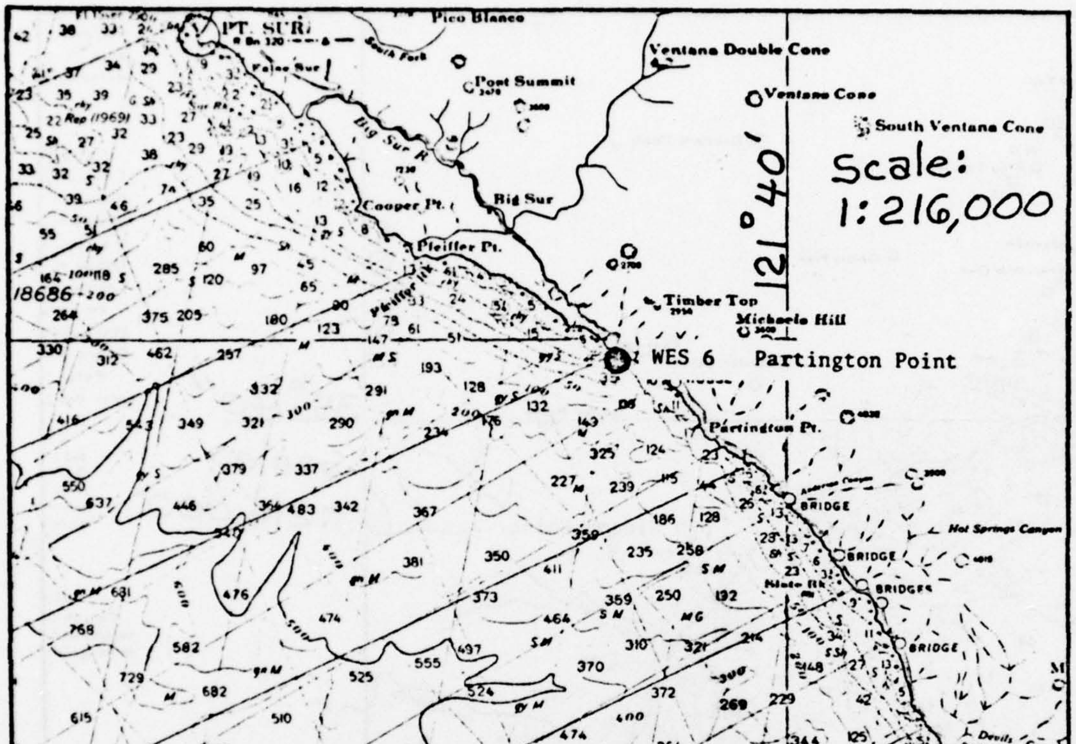


Figure 9. Partington Point potential LNG terminal site

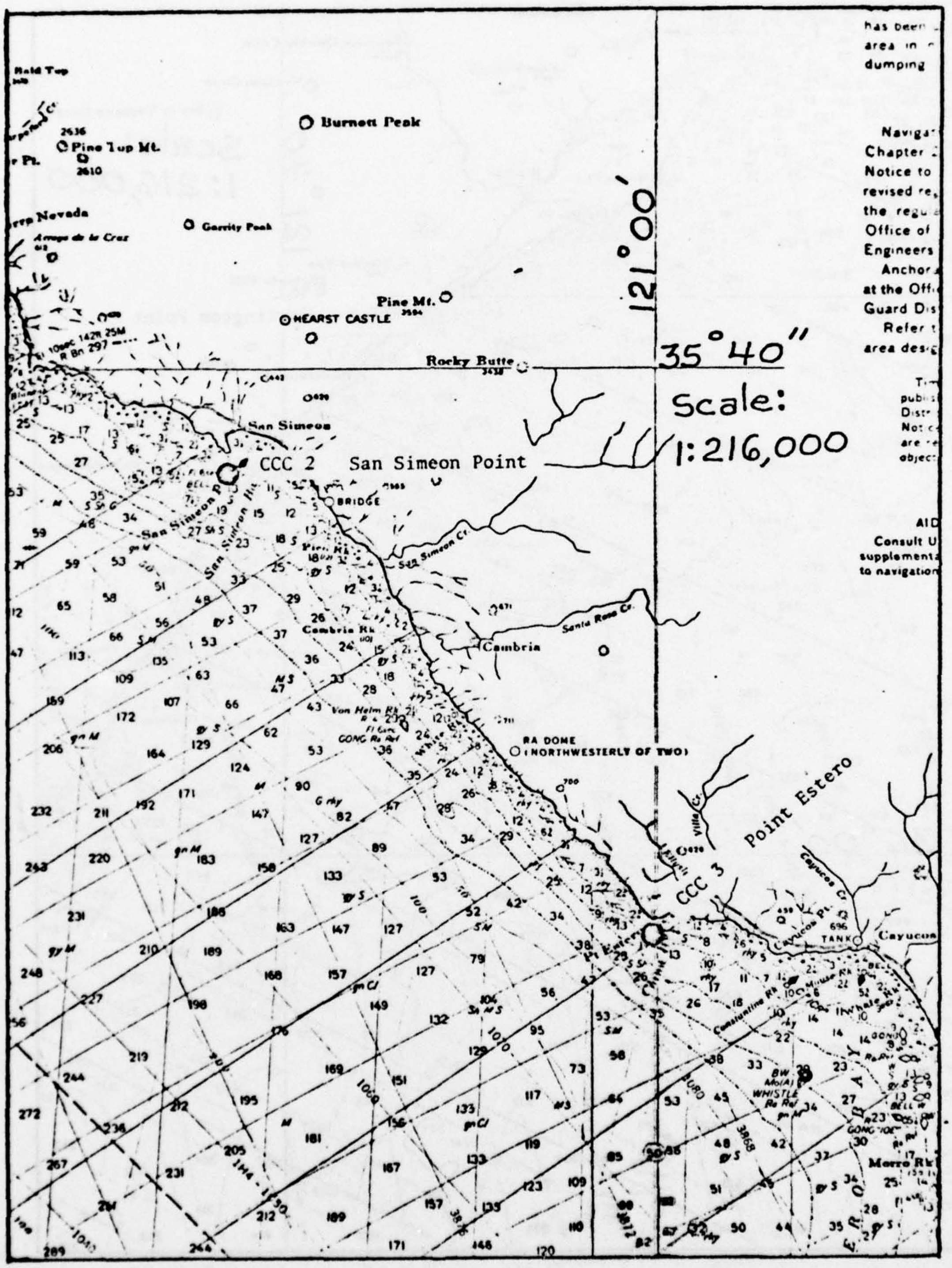


Figure 10. San Simeon Point and Point Estero potential LNG terminal sites

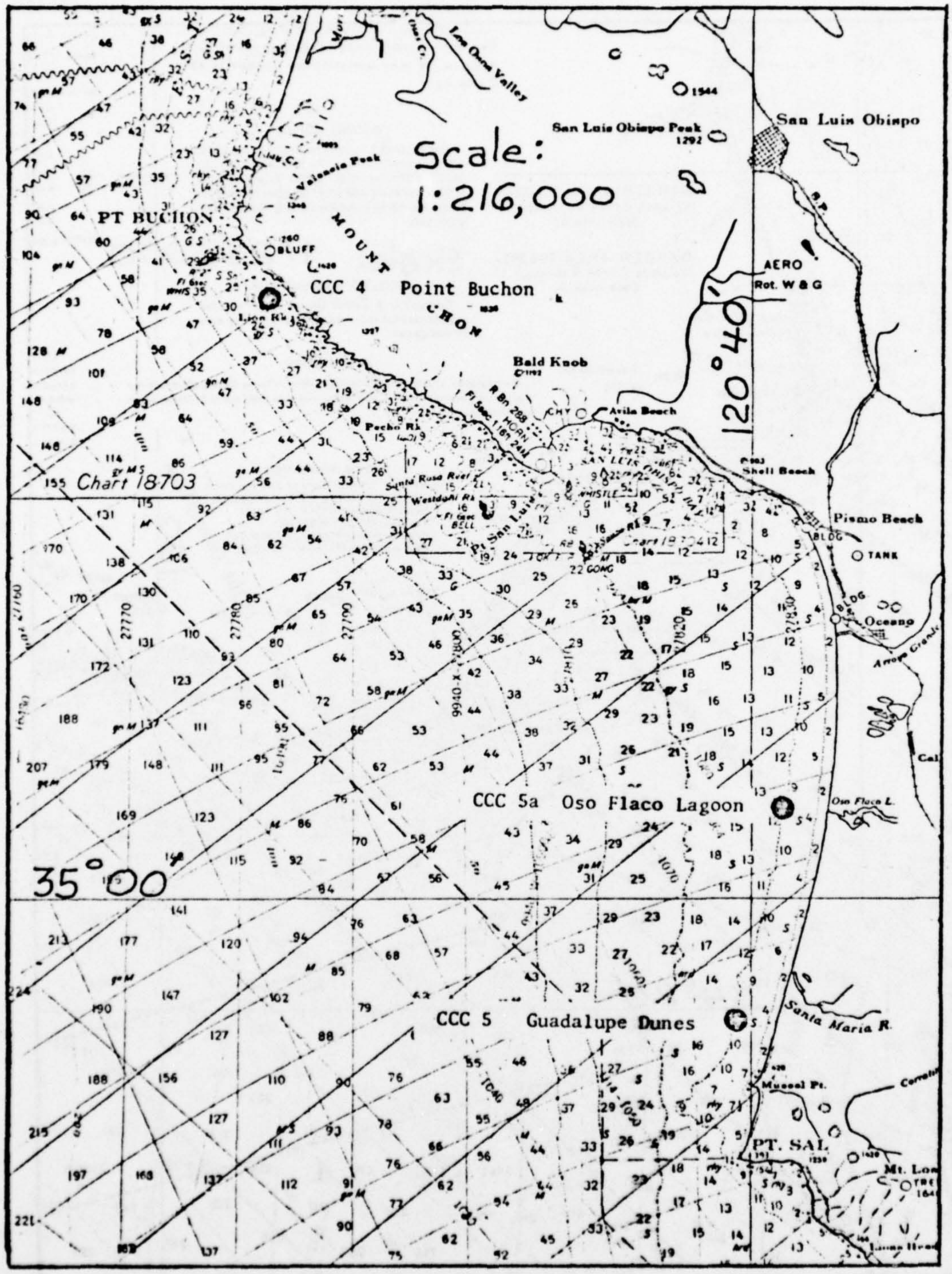


Figure 11. Point Buchon, Oso Flaco Lagoon, and Guadalupe Dunes potential LNG terminal sites

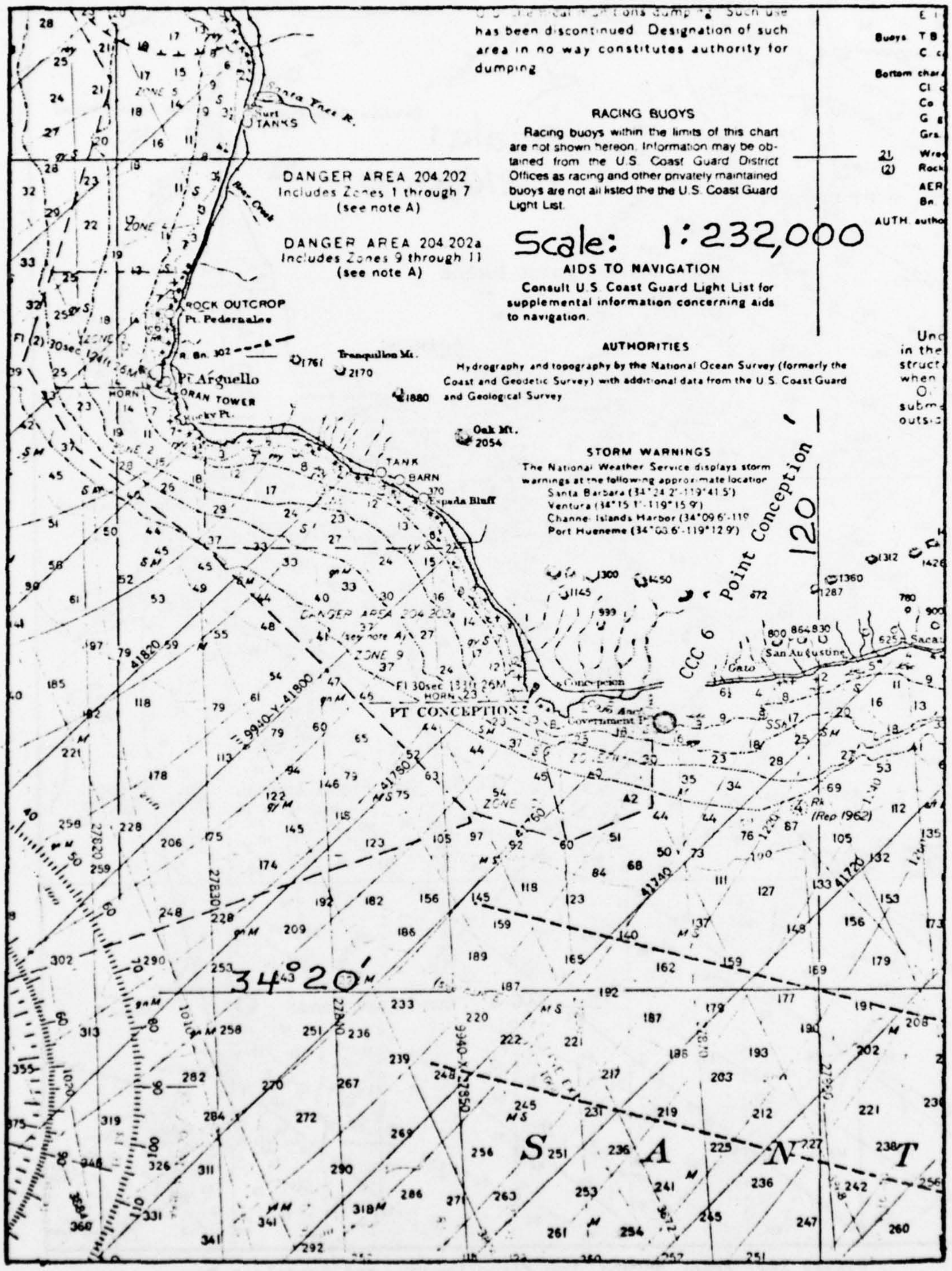


Figure 12. Point Conception potential LNG terminal site

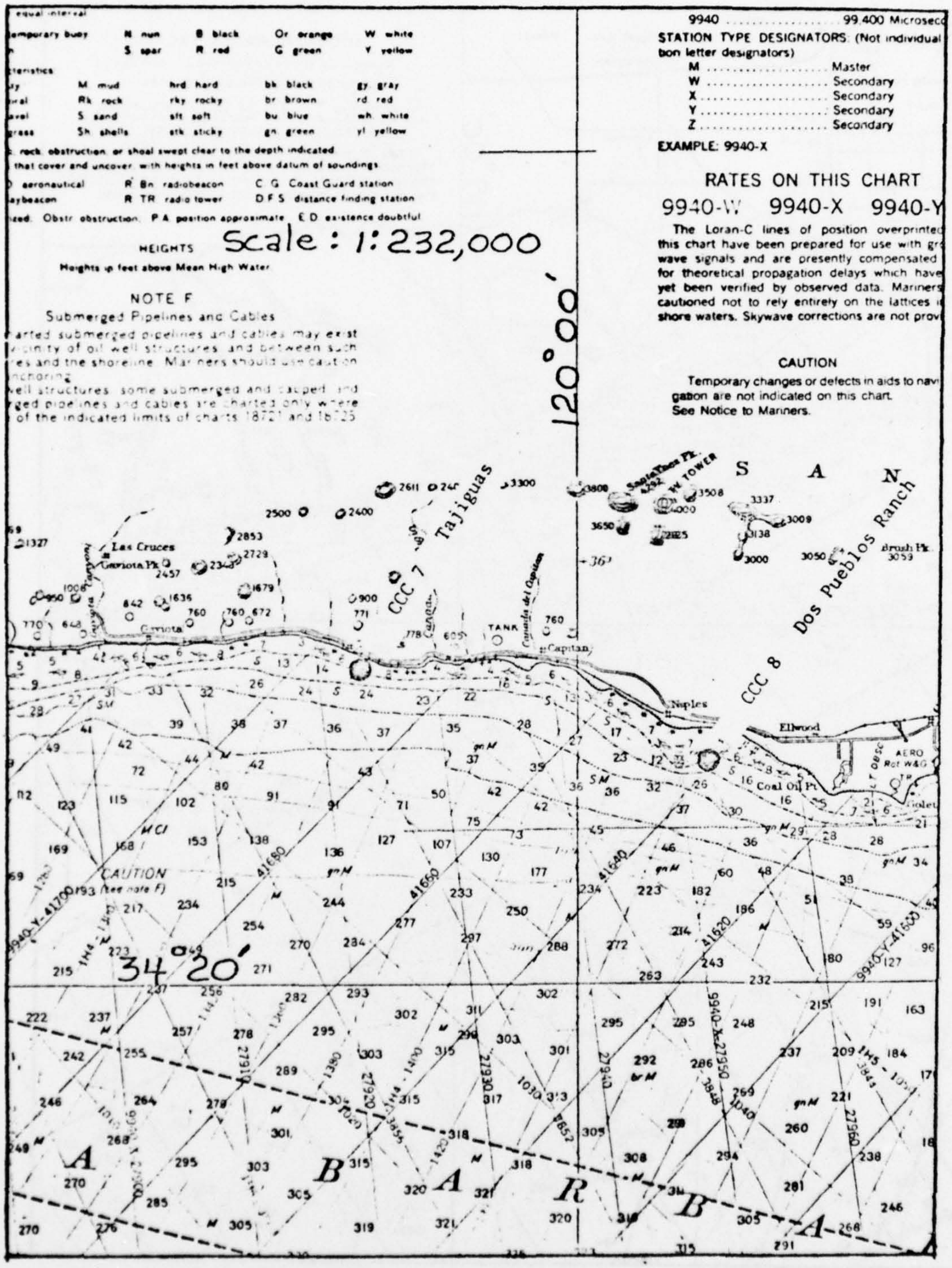


Figure 13. Tajiguas and Dos Pueblos Ranch potential LNG terminal sites

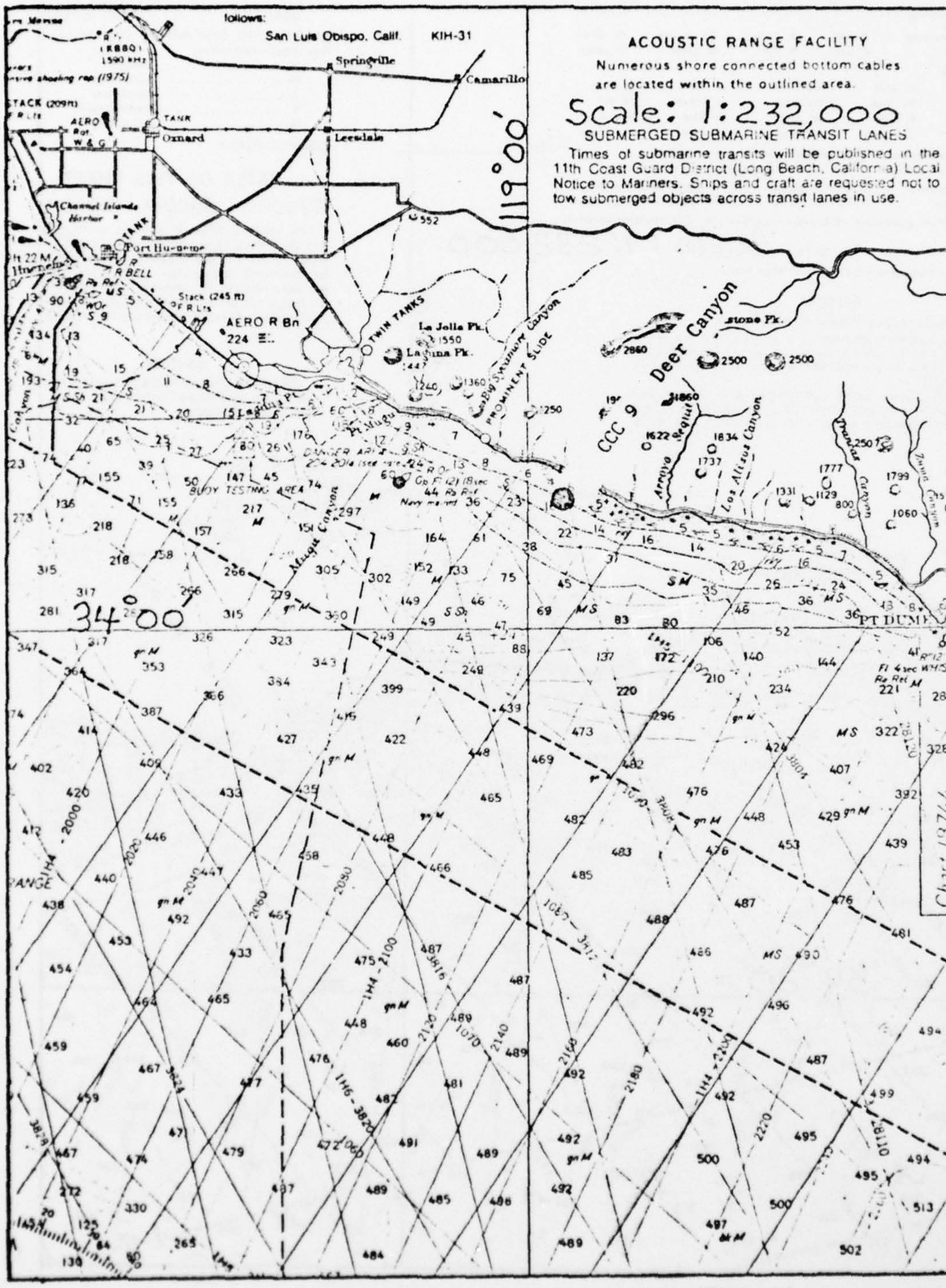


Figure 14. Deer Canyon potential LNG terminal site

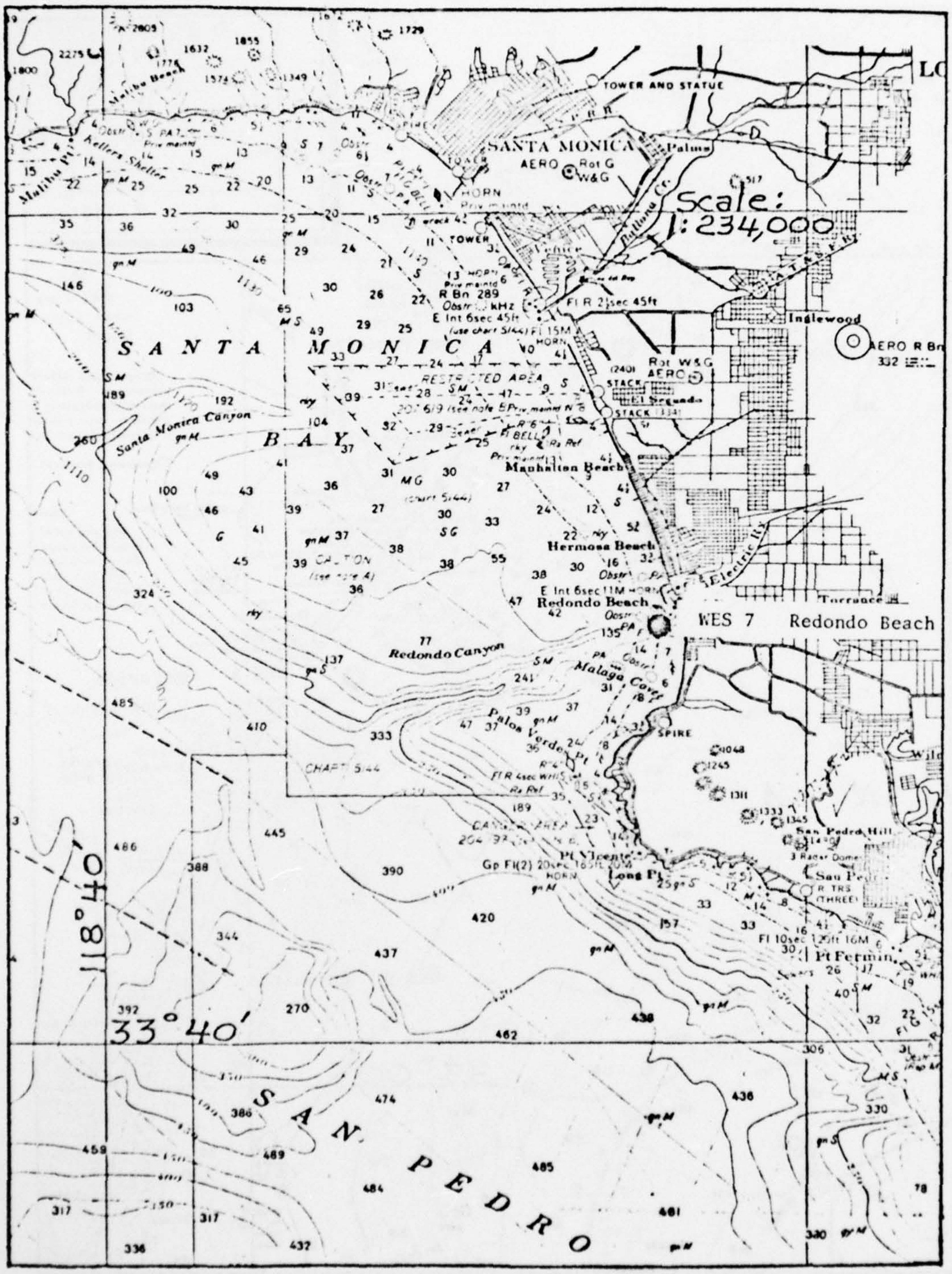


Figure 15. Redondo Beach potential LNG terminal site

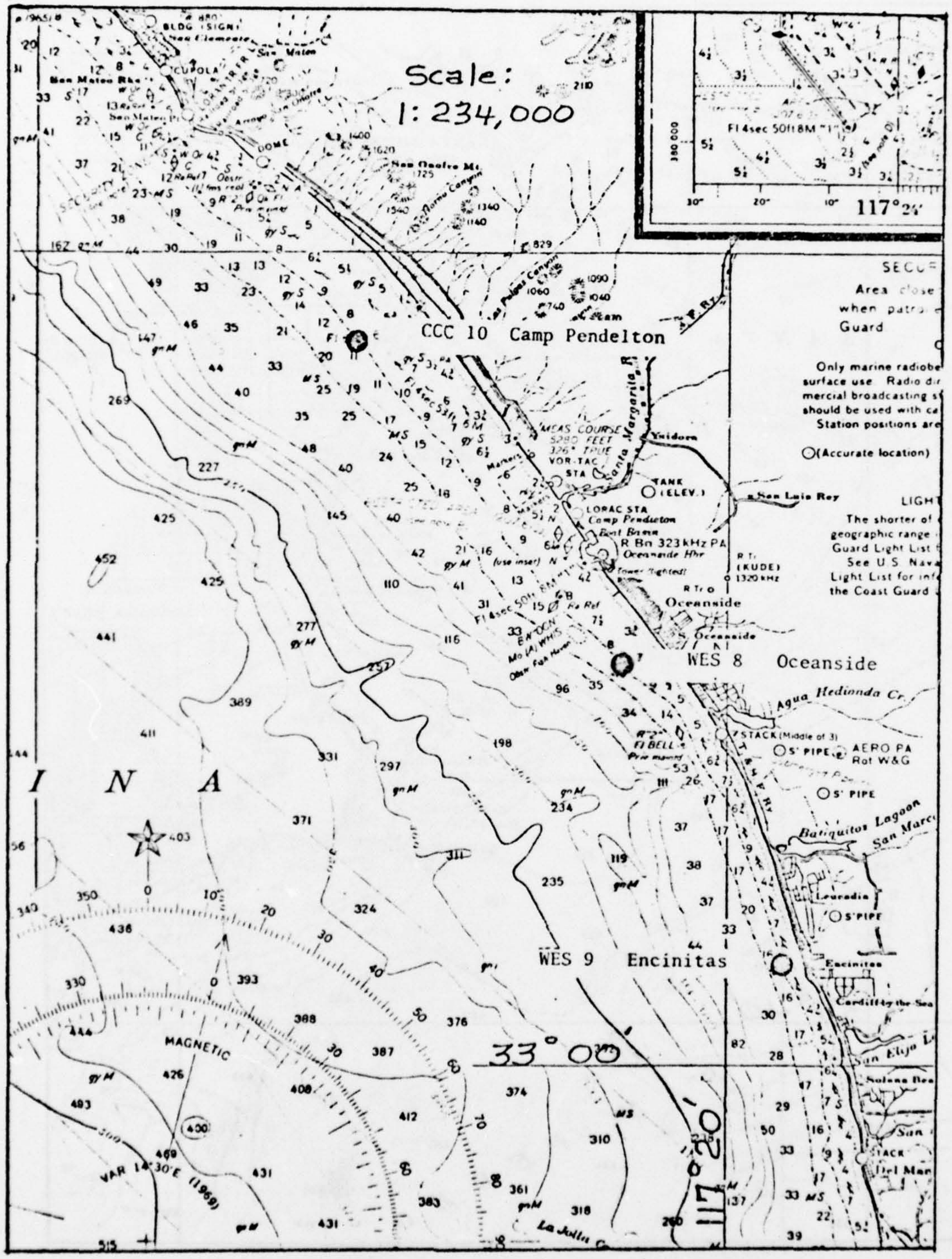


Figure 16. Camp Pendelton, Oceanside, and Encinitas potential LNG terminal sites

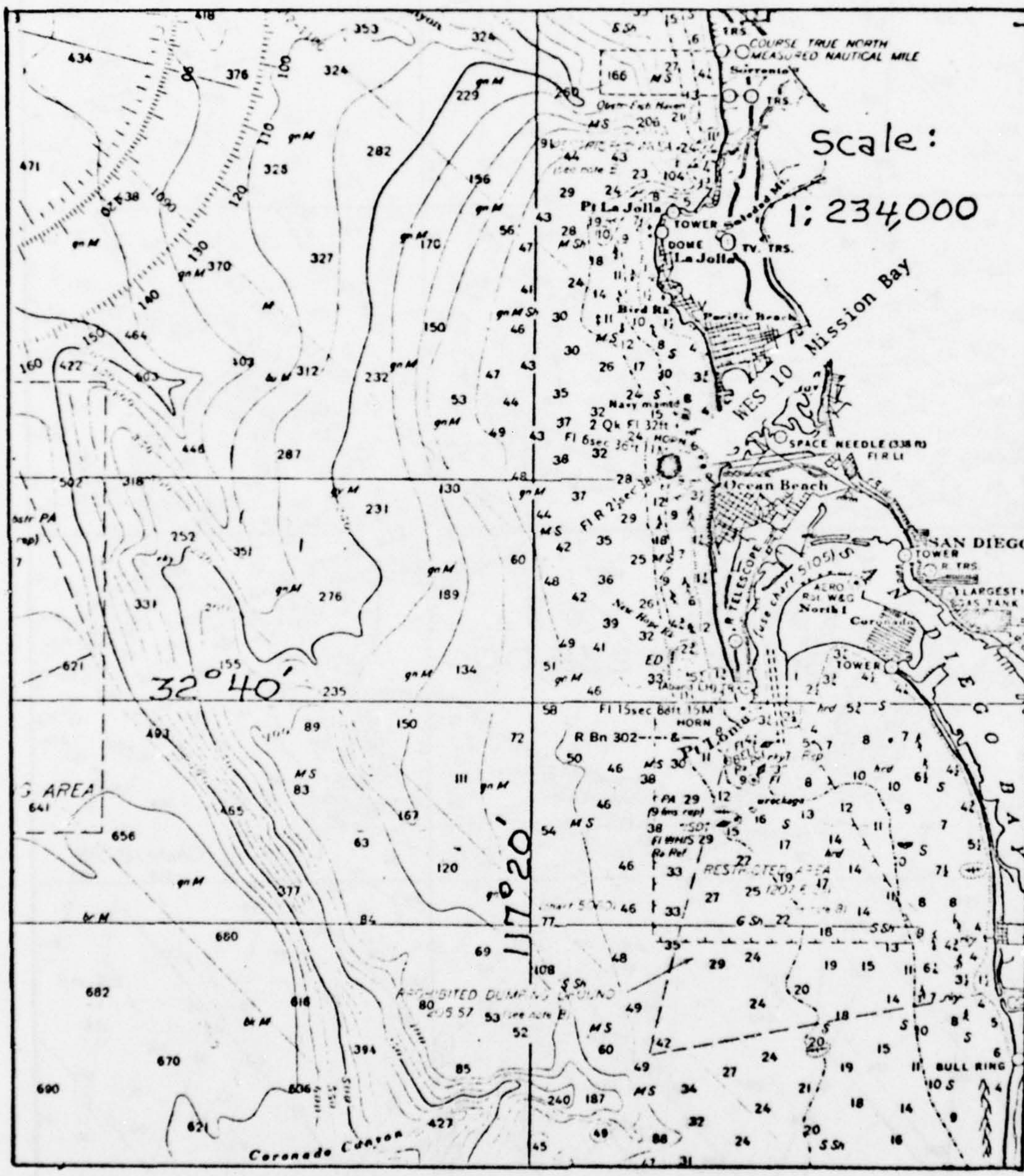


Figure 17. Mission Bay potential LNG terminal site

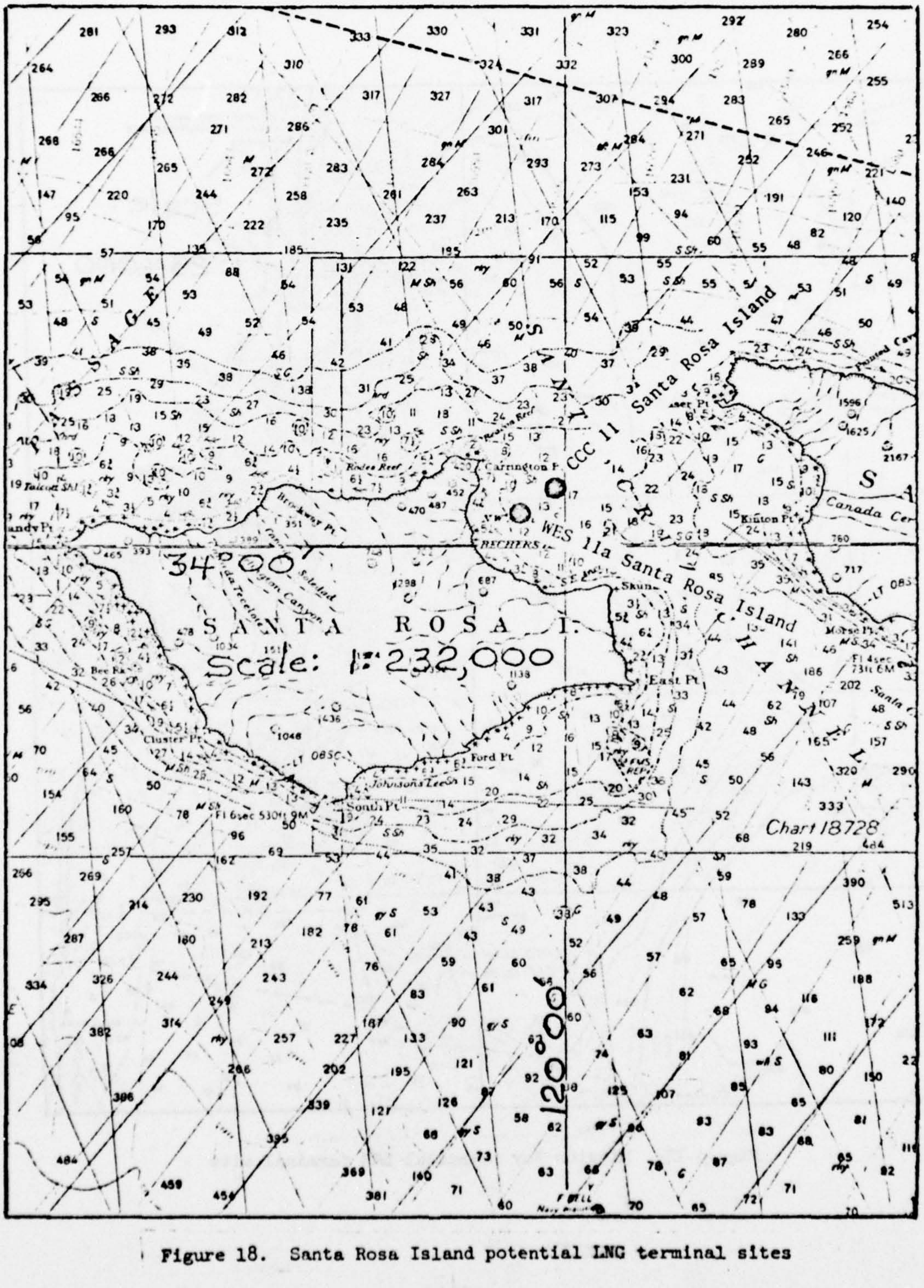


Figure 18. Santa Rosa Island potential LNG terminal sites

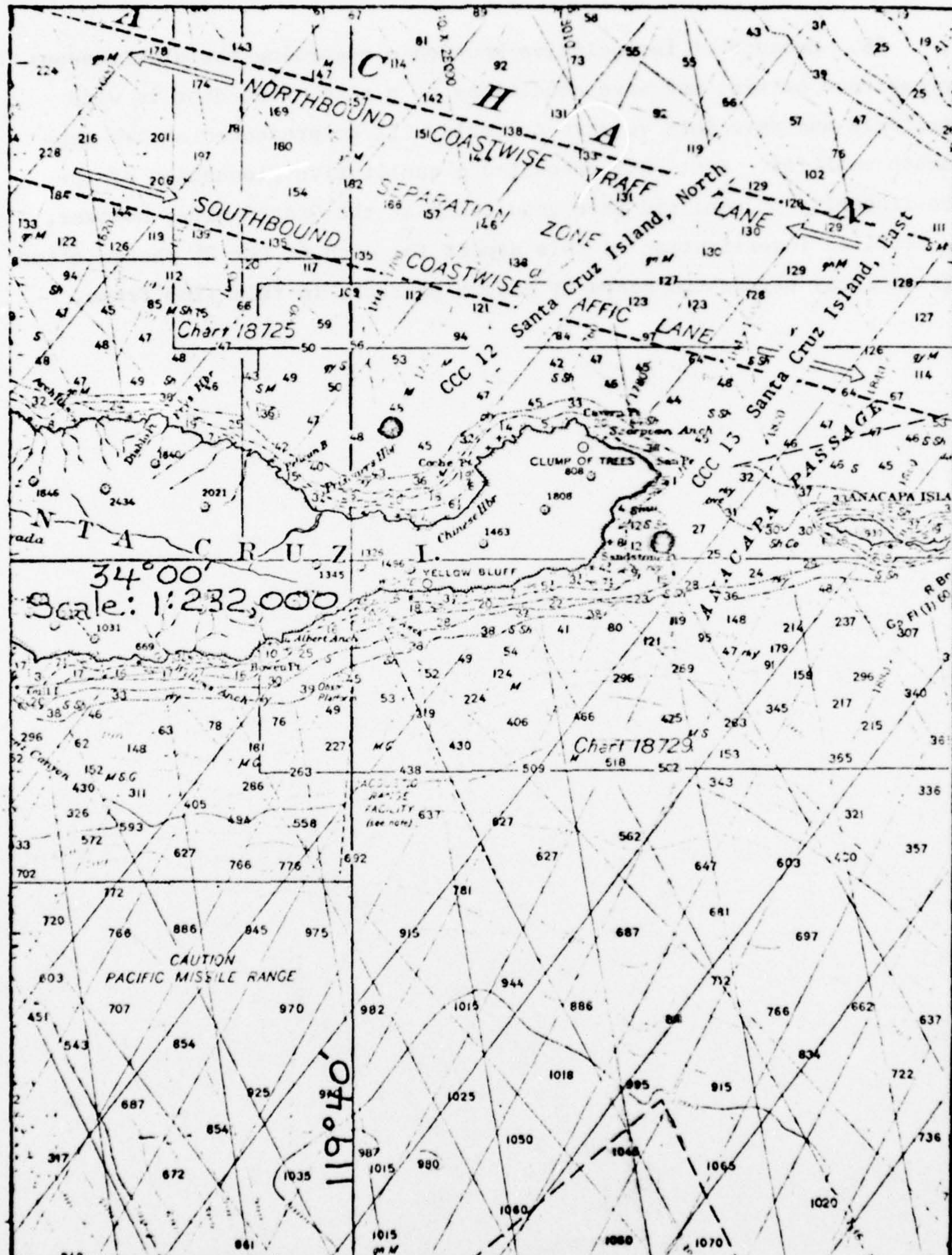


Figure 19. Santa Cruz Island potential LNG terminal sites

10. Because of inconclusive knowledge regarding the simultaneous occurrence of wind and wave conditions at a site, wind data vs wind criteria and wave data vs wave criteria will be presented as two separate entities. Kent[1] has presented a qualitative discussion of the co-linearity of wind and wave conditions at the Oxnard site; however, a detailed investigation of this aspect for each of the 26 chosen sites is entirely beyond the scope of effort possible in this time frame.

PART II: MAJOR METEOROLOGICAL FEATURES

11. Each of the 26 areas of interest is exposed to a broad spectrum of wave characteristics through an angular section of the compass . depending on the particular location. Because of physical boundary conditions, however, only a limited bank of wave conditions affect each region. In order to appreciate the overall wave climate existing at each potential LNG site, some knowledge of the relevant wave generating characteristics is required. A brief description of the major meteorological features is presented, following the style of Kent[1], and after Meteorology International Inc.[2]

Pacific High

12. The Pacific anticyclone plays an important role in the generation of waves along the California Coast. This is particularly true during the summer months when it is the dominant feature of the meteorological circulation in the eastern North Pacific. During these months the predominant wave action, particularly in southern California, is almost invariably generated by the prevailing west-northwest to northwesterly winds along the Pacific coast of the United States. These wind strengths are dependent upon the offshore pressure gradient, and the gradient itself is dependent upon the interplay of the location of the Pacific High with the thermal trough over central California and Nevada.

13. A very common situation, particularly in the spring, occurs when a mass of cold air drops into southern Nevada resulting in the formation of a rather intense surface low pressure system. As high pressure builds in behind the low, a tight pressure gradient develops resulting in extremely strong west-northwest to northwest winds along the coast.

Extratropical Cyclones

14. Extratropical cyclones represent the most important source of severe waves reaching the California coast. Normally, these storms originate in the vicinity of Japan and proceed eastward across the Pacific to the Gulf of Alaska. Waves generated in the southwest sectors of these storms reach most of California but usually show a steady decrease in energy intensity southward along the coast. Very often, however, especially during the winter and spring, the Pacific anticyclone shifts southward, permitting the more intense extratropical cyclones to follow a more southerly course and affect the lower part of the state. When these storms approach the California coast the topographic influence is such that the prefrontal southerly winds right on the coast tend to be somewhat more intense than the following westerlies. However, the opposite is true while the disturbances are still at sea, and an intense buildup of easterly directed wave energy results. As the storm approaches the coast the westerly winds normally will decrease slightly and the wave energy front will decay as it travels shoreward. The decay distance usually increases going to the south, but it is possible, with some storms, for the maximum wave energy to be centered upon central or even southern California.

15. Southern California generally experiences its most severe wave condition when these extratropical systems develop storms between Hawaii and the Pacific coast. This condition occurs when the Polar front trails south westward and approaches a col in the high pressure belt. Cyclogenesis results, and if the contrast between the warm tropical air and cold polar air is great enough, the storm will move toward southern California with strong south to southeasterly prefrontal winds and strong post-frontal westerlies. Waves then will be high from these directions, though of different spectral characteristics.

Tropical Cyclones

16. Along the west coast of Mexico the tropical cyclone (Chubasco) is a regular meteorological phenomenon during the months of July through October, occurring on the order of six times annually. Generally speaking, these cyclones follow one of two main tracks: (1) along the Gulf of Tehuantepec northward following the mexican coast and inland near Mazatlan; or (2) starting with a more westerly origin and proceeding west to west-northwesterly toward Hawaii. Since 1900 only six or seven of these tropical cyclones are known to have come as far north as California, and only one of these was of marked influence with respect to wind and waves. Waves on the order of 15 ft in height from about 180° occurred along the coast of southern California. Consequently, waves from this generating source are low and of a small frequency of occurrence.

Southern Hemisphere Extratropical Cyclones

17. Wave measurements made during the summer months at La Jolla and Oceanside, California, show the characteristics of very long periods and of a southerly origin (13 to 20 seconds). Several factors suggest that this swell comes from extratropical cyclones proceeding from west to east across the south Pacific Ocean between Australia and Chile. This swell is generated by winds associated with storms of the austral winter in the south Pacific, storms of much greater size and intensity than those of the northern hemisphere. This swell occurs in significant amounts from May through October and while seldom greater than 4 ft in height, may be very important at many locations because of its long period.

PART III: DATA SOURCES

Synoptic Shipboard Meteorological Observations (SSMO)

18. The NOAA/EDS Synoptic Shipboard Meteorological Observations (SSMO) tape data family was derived from over 31 million surface marine observations on a variety of punched card decks. Observations were obtained from ship logs, ship weather reporting forms, published ship observations, automatic observing bouys, teletype reports, and on cards purchased from several foreign meteorological services. The quality of instruments used to make the observations ranged from those found aboard a 19th century whaling ship to the most sophisticated electronic equipment used on today's ocean weather ships. Observer qualification varied from deck hand to trained meteorologist. From this conglomeration an effort has been made to bring to the researcher of oceanic weather patterns and sea conditions, a common observational format, designed for use with modern electronic data processing equipment.

Marine Advisers Southern California Wave Characteristics

19. The purpose of this investigation was to develop statistics which would present a detailed analysis by direction, height, and period of the frequency of occurrence of various types of ocean wave characteristics of southern California waters. It was intended that data from the years 1956-1958 only should be used, but such data were not always available and deviations from this original intention were noted occasionally. The method of investigation involved obtaining historical weather maps and/or other weather records and information covering all significant wave-generating areas for the specified years, and then hindcasting the waves which would have resulted according to

Bretschneider's modification of the Sverdrup-Munk theory. In order to accomodate the widest possible range of conditions the wave generation graph was extended to its limits by using the extreme values of the nondimensional parameters utilized in this theory.

20. Hindcasts were made by Marine Advisers[3] for three definite locations. One of these stations is exposed to open ocean influences from southeast through west to north-northwest, and is considered to be representative of conditions outside the offshore islands. The other two are representative of conditions in the more protected waters near the mainland shore.

21. Ocean waves off the coast of southern California fall easily into one of three main catagories: Northern Hemisphere Swell, consisting of waves which were generated in the northern hemisphere but which arrived at the three stations after leaving the generating area; Southern Hemisphere Swell, consisting of similar waves generated south of the equator; and Sea, consisting of waves which were generated within the local area (i.e., within approximately 200 miles of the stations).

22. The fundamental limitations on this kind of an investigation must necessarily derive from the weather data on which the investigation was based. Where weather maps are used, two limiting factors are involved. The first concerns the accuracy of the data. Opportunities for error, both human and mechanical, exist at many places in the chain of activities stretching from the weather itself to the symbol on the map. The initial observation may be more or less correct, depending upon the skill and experience of the observer and the condition of his instruments. However, misrepresentation during encoding can occur, and experience and care remain important when the information is being transferred to a map.

23. The second major limitation concerns the subjectivity of weather analysis in general. In considering the oceanic regions of a weather map, the weather forecaster inevitably encounters large areas wherein data are scant or nonexistent. The configuration he draws then

becomes in large measure a reflection of his own judgment and experience. Under these circumstances it is obvious that no two forecasters will produce identical analyses, and it is not unusual to find them in considerable disagreement. Such uncertainties can seriously affect a wave hindcast since moderate differences in isobaric spacing can result in significant differences in the wind speeds they imply, and small variations in isobaric orientation can make the difference between a resulting wave train hitting or missing a distant point.

24. Ultimately the wave hindcaster for Marine Advisers for the most part accepted the work of his meteorological predecessors and on it imposed his own set of subjective interpretations, among which include the size and persistence of fetches, the intensity and direction of their winds, and other interpretive factors.

National Marine Consultants Wave Statistics for Seven Deep Water Stations Along the California Coast

25. Wave hindcast studies were conducted by National Marine Consultants[4] for the purpose of compiling deep-water wave statistics based on meteorological records and charts for the years 1956 through 1958. The tables were developed as wave height, period, and direction, and presented as monthly and annual averages for significant values. The general area of study covered the entire coast of California and was presented by seven carefully selected deep water stations.

26. Economic considerations restricted the hindcast study to the use of three years of data. This number of years was felt to be a minimum for any significance, and it was anticipated that additional years of data would eventually be averaged with these to provide statistics with smaller confidence limits.

27. Since wave height-period-direction conditions at a given location are a function of weather patterns, and since such patterns are extremely variable, the choice of years for this study became very

important. In terms of weather there is practically no such thing as an average year, and it would be defeating the purpose to choose three years which are "about" average or to select three years at random.

28. The years 1956, 1957, and 1958 were chosen for analysis for the following reasons: (1) These years were significantly different from one another in terms of storm frequency, but different in such a manner as to have a compensating result; and it was felt that this result would be representative of an "average" year. (2) It was felt that recent years (at the time of the study) would (a) be more representative in view of gradual changes in world wide weather patterns and (b) contain reasonably accurate synoptic weather observations due to the increasing number of reports from ships at sea and proficiency in measuring techniques relative to the pre-World War II period. (3) Consecutive years were chosen to maintain hindcasting continuity with the anticipation of adding subsequent contiguous years.

29. Southern hemisphere swell was not evaluated in this study because it was felt to be of minor importance relative to North Pacific wave intensity at all seven study stations.

30. Without instrumental verification, it obviously is not possible to make any definitive statement to the accuracy of a wave hindcast. If it can be concluded that the theory provides reliable values, then much of the requirement for success hinges upon the forecaster's/hindcaster's experience. In this regard, the wave forecasting division of National Marine Consultants had been applying both the SMB and PNJ theories for several years for several locations along the California and Oregon coasts. These forecasts have had considerable checking out and verification by clients, using both instrumented and visual means, and have proven to be relative accurate for the most part.

Department of Navigation and Ocean Development Deep-Water Wave Statistics for the California Coast

31. The ocean wave statistics that hitherto have been in general

use by coastal engineers for the California coast were derived in 1960 and 1961 from three years of synoptic weather maps. This work was carried out by National Marine Consultants and Marine Advisers on behalf of the Department of the Army, U. S. Corps of Engineer Districts.

32. In order to extend the data base and provide a wider range of useful statistical formats, the Department of Navigation and Ocean Development (DNOD) of the State of California began work in 1975 with the U. S. Navy Fleet Numerical Weather Central (FNWC) and the Naval Postgraduate School. In March 1976 a document was prepared outlining "Specifications for the Production of Ocean Wave Statistics for the California Coast from FNWC Singular Wave Analyses". These specifications formed part of a contract placed in June 1976 with Meteorology International Incorporated (MII) who was selected by DNOD to produce the required ocean wave statistics. The specifications called for ocean wave climatologies, specifically designed for coastal engineering applications and based on FNWC wave analyses, for six representative deep-water stations off the coast of California, extending from the Oregon border to the Mexican border. The results were presented by Meteorology International Incorporated[5] in 1977 and were derived from 29 years of wave hindcasting by the FNWC. This study provides the greatest amount of historical data on deep-water height, period, and direction yet assembled for the California coast.

33. Essentially, a "wave model" is an algorithm for deriving a wave field from a wind field. Again in essence, the wind field is stored in a grid-system, covering, for example, the northern hemisphere with a large number of uniformly spaced grid points. The winds stored at each grid point are used, by means of a mathematical process, to generate sea waves at each grid point. The sea waves radiate from each grid point and propagate to other grid points as swell. This information is collected to give a swell field. Given these two parameters, the combined wave height may be determined.

34. However, there are two possible approaches. The more recently developed and sophisticated one is to "store" at each grid point the

energy spectrum for sea and swell. Since swell is due to wave generation at grid points other than the one under consideration, the direction of sea-wave propagation also must be stored to ascertain how other grid points will be affected. The wave spectra are stored by "slicing" the spectra into an acceptable number of frequency intervals, the number of slices depending on computer capacity available. For example, on one particular model the analyzed wave spectrum at each grid point is represented by a 15-frequency by 12-direction matrix. This type of model is called a "Spectral Wave Model".

35. A simpler approach is to store at each grid point only the significant wave height, period, and its direction of propagation, and to initiate and propagate only one swell component from each grid point. This type of model is called a "Singular Wave Model".

36. At the time the MII study was commenced, the only existing data base available for tabulating a wave climatology at the six MII stations had been derived using the FNWC Singular Sea/Swell model. Thus the statistics presented in these reports are based on results from a singular wave rather than a spectral wave model.

37. Only northern hemisphere swell and sea conditions were evaluated by Meteorology International Incorporated.

Data Source Selection

38. The specific locations of the data stations developed by Marine Advisers (MA), National Marine Consultants (NMC), and Meteorology International Incorporated (MII), are shown in Figure 20. The Synoptic Shipboard Meteorological Observations (SSMO) data tapes can be accessed for processing at any specific location desired. However, since these are observations obtained from predominately ships at sea, the number of observations decreases rapidly as a position near shore is requested. Hence, in order to keep the statistical variance at an acceptable level, it is essential that the distance from shore be large enough to

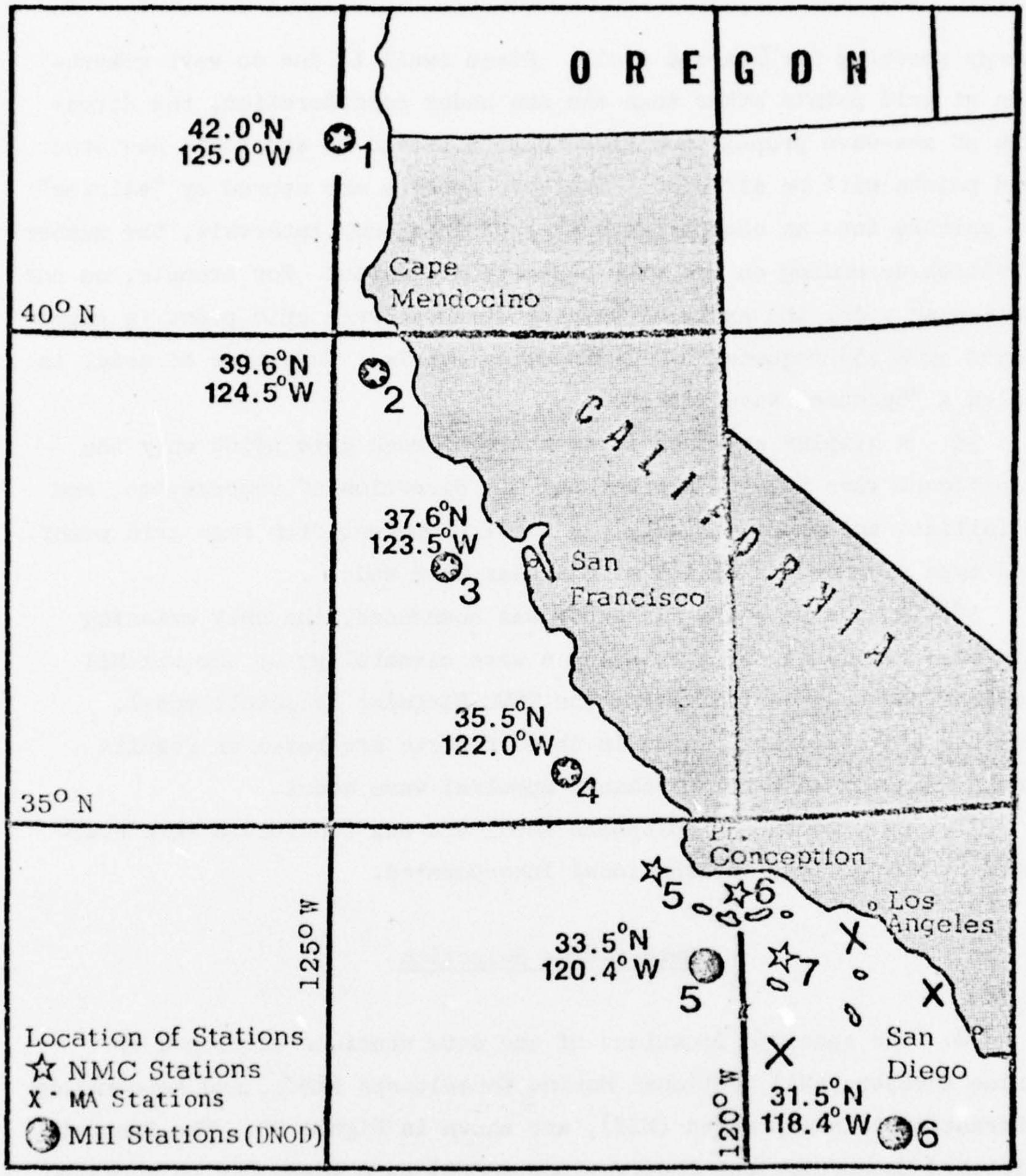


Figure 20. Locations of deepwater data stations off the coast of California, for National Marine Consultants, Marine Advisers, and Meteorology International Incorporated (after MII)

intercept the nations' shipping lanes. Accordingly, and in order to facilitate comparison of the two data sources, the SSMO data tapes were processed at the same locations as the DNOD (MII) stations, which also coincided with the first four NMC stations.

39. It was the concensus of opinion that, taking into account all the ramifications eluded to in the aforementioned studies, the DNOD data for the unsheltered deep water conditions probably formed the best data base of those considered. Thus the DNOD statistical tables were used exclusively for sea conditions and northern hemisphere swell north of Point Conception. These data do not contain southern hemisphere swell information. Since the Marine Advisers data provides the only readily available source of southern hemisphere swell characteristics, the DNOD statistics were supplemented with the values of southern hemisphere swell from Marine Advisers.

40. The southern hemisphere swell from Marine Advisers was developed for a station near the coast of southern California. These data were used in their entirety (the portion which applied at a specific potential LNG study site) throughout the entire extent of the California coast without decaying in a northerly direction. The justification for this action comes from the fact that the swell originated thousands of miles away in the southern hemisphere and has experienced significant decay in arriving at the hindcast station; hence a few hundred miles of further propagation to the northern California border should not appreciably alter the characteristics.

41. The evaluation of wind and wave effects on the selected potential LNG terminal sites north of Point Conception is rather straightforward. However, those sites south of Point Conception are an entirely different matter as this complete stretch of coastline is shielded or sheltered to a significant degree by the offshore islands. The only source of hindcast data between the islands and the southern California coast is station 6 of National Marine Consultants. This station was therefore used in conjunction with the DNOD data and the southern hemisphere swell from Marine Advisers.

42. Because of the east-west orientation of the coast line adjacent to Santa Barbara, it was necessary that station 6 of NMC be treated somewhat differently by NMC than were the other stations. This requirement was brought about by the fact that swell arriving at station 6 from the prevailing west-northwest direction would have to be interpreted as having no effect upon the Santa Barbara-upper Ventura coast. This, of course, is not true since there is always a west or west-southwest component of swell present in the Santa Barbara Channel except in cases of strong southeasterly winds. To take this fact into consideration two things were done: (1) the "west" direction category was extended to include 290°; (2) for west-northwest swell arriving at angles greater than 290°, a westerly component was computed and included in the statistics. The significant height of this component swell train was based on forecast experiency by NMC personnel in the Santa Barbara area. The only inconsistency arising from such a method is the fact that a portion of the coast line south of Santa Barbara would receive the effect of both the west-northwest and the west swell. However, the energy of the latter is small relative to that of the former, and the resultant additional energy is of little significance.

43. A second matter pointed out by NMC is the fairly high incidence of short period, southeast wave action at station 6 and short period, northeast wave action at station 7 during the months of November and December. This wave activity is the direct result of Santa Ana winds blowing over southern California. Resultant waves are northeasterly at station 7, but because of angular dispersion in the wind and wave fields, are southeasterly at station 6. Of course, some of the southeast wave condition at station 6 in November and December also is due to winter conditions, but this is of a somewhat larger period. This action also extends through the spring whereas the Santa Ana does not.

Island Sheltering Theory

44. The coast of southern California below Point Conception is shielded to a considerable degree by the offshore islands which

effectively block a large portion of the wave energy known to exist at the deep water stations. The techniques for treating this sheltering effect as developed by Arthur[5] and applied by Marine Advisers were used for transferring the deep water wave statistics of DNOD stations 5 and 6 past the barrier islands.

45. In investigating island sheltering, the first consideration is to determine which directions of approach are open to waves of various periods and which are blocked. This cannot be accomplished by simply inspecting the sea level contours of the islands, for shoal water can act as barriers just as effectively as an island shore. The blocking action depends on both water depth and wave period, with long-period waves requiring deeper water for passage than short-period waves; and as a result, any given opening between two islands will present a narrower portal to a long-period wave than it will to a short-period one. With the aid of precise bottom-contour charts, all such avenues of approach were listed, and the required integrations were performed by digital computer. The theory yields not only height-reduction ratios but indicates modification in direction as well. Periods are assumed to remain unchanged.

46. The direction modifications are necessary because in some cases sheltering will block out part or all of the primary central portion of the direction sector of a train of approaching waves. When this happens, the wave energy reaching the hindcast point will obviously come from around the two ends of the barrier, and the resulting modified wave train will come from a direction within the original sector but modified toward that end of the barrier around which the larger part of the remaining wave energy came.

PART IV: SIX FOOT ACCEPTABLE WAVE HEIGHT CRITERIA

47. The extent to which the effectiveness of a marine terminal is reduced by excessive wave conditions is a direct function of the angle of exposure to the open ocean, the significant height of the wave regime for various periods, the orientation of the terminal, and the duration of wave attack from various sources. From a cursory review of the data base selected for utilization by this study, it was readily apparent that southern hemisphere swell did not exceed 4 ft in height even at the deep water stations. Since refraction effects are being ignored in the present analysis, this precluded the occurrence of swell waves from the southern hemisphere entering the examination since waves up to 6 ft are considered to have no adverse effect on the tanker operations.

48. The angle of exposure to the open ocean is a site-specific item unique to each individual location. For this reason, values ascertained for one potential site cannot be readily transferred or interpolated for another site even relatively nearby unless the exposure windows are essentially the same. The criteria presently under consideration is independent of terminal orientation and direction of wave approach as long as the direction of approach is restricted to that permitted by the physical boundary conditions.

49. Since northern hemisphere sea and swell are the only wave characteristics affecting availability of the proposed terminals, these data are primarily being obtained from the DNOD statistics, except for those stations shielded by the channel islands south of Point Conception. Even here, the deep water DNOD statistical data are analytically transferred past the islands using the island sheltering techniques, and except for slight changes in directions of approach and reduction in wave heights, the inherent characteristics are retained.

50. It was observed that not only is there a seasonal variation in sea heights at a specific deep water station, there also is a spatial variation which causes a reversal in the seasons of the year when the maximum sea heights occur. That is to say, during the winter months

seas are much higher in northern California waters than during the summer months. Quite the opposite is true for the open sea waves of southern California. Here the higher waves occur during the summer months and appear to be greater in height than the summer waves in northern California. At some point near mid-state, possibly in the Monterey Bay region, there appears to be a minimal variation with season for the wave heights.

51. The DNOD deep water data are summarized and presented for consideration with sea characteristics shown in Figures 21 through 26 for DNOD stations 1 through 6, and the northern hemisphere swell characteristics are shown in Figures 27 through 32. The first 4 years of record are erroneous for the aforementioned figures and should be disregarded.

52. Northern hemisphere swell does not exhibit the reversal with distance along the California coast which the sea conditions display, although there is a decrease in intensity from the winter months in the north to a more uniform spread throughout the year in the southern part of the state.

53. The extent of the sea height reversals are quantified by averaging the corresponding day of each year of record and displaying the results graphically as a plot of time vs wave height. Here the extreme variations that occur from day to day are removed by smoothing with a three consecutive day average. These results are presented in Figures 33 through 38, and are enlightening because they emphasize the extent to which seasonal influences are felt throughout the state, and thus may carry implications regarding optimum scheduling of operations.

54. Histograms have been prepared for each of the 26 potential LNG terminal sites of interest and convey the maximum number of days each year that a particular location will be subjected to waves of specific heights, on the average. These histograms are presented in Figures 39 through 64 and provide an indication of the sensitivity of the downtime to the criteria specified, on an annual basis. For these data which exceeded 6 ft in height, a monthly determination was made for each potential LNG station, and the results displayed in Figures 65 through 90.

55. The over-whelming majority of the wave energy incident to the California coast comes from the northwest quadrant of the compass. This is evidenced by the tremendous sheltering effect which the offshore islands have on that section of coastline south of Point Conception. While those sites on the northern side of Santa Rosa and Santa Cruz Islands receive a considerable amount of wave energy from the west and northwest through the Santa Barbara Channel, that site on the east end of Santa Cruz Island is almost completely shielded from all waves in excess of 6 ft. By expeditiously relocating site CCC 11 on Santa Rosa Island to site WES 11a, thereby effectively removing all exposure to both northern and southern swell, the days/year that the site experiences waves in excess of 6 ft is reduced almost in half, and is correspondingly true when more stringent criteria are applied.

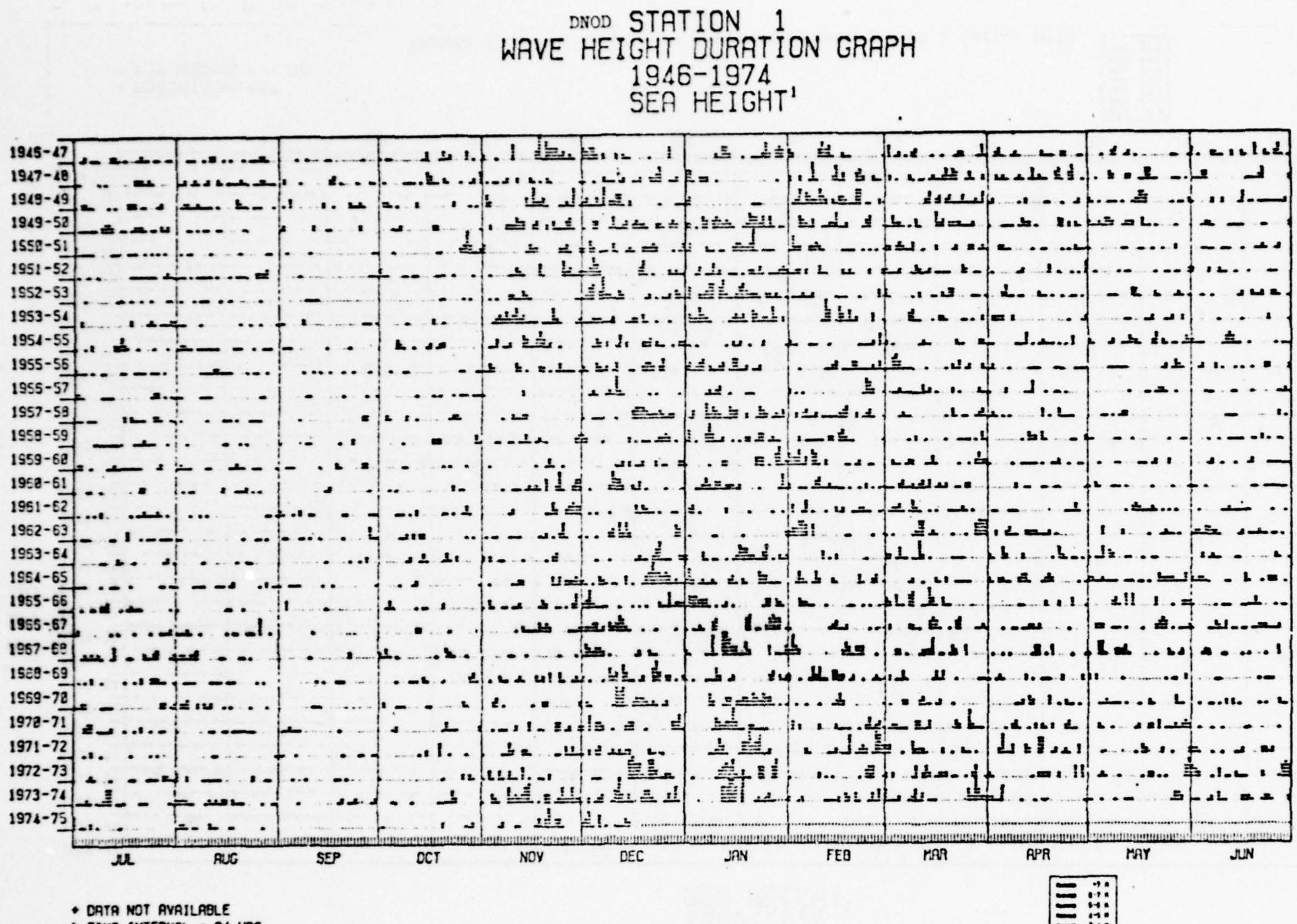


Figure 21. Sea heights at deepwater station DNOD 1 (after MII)

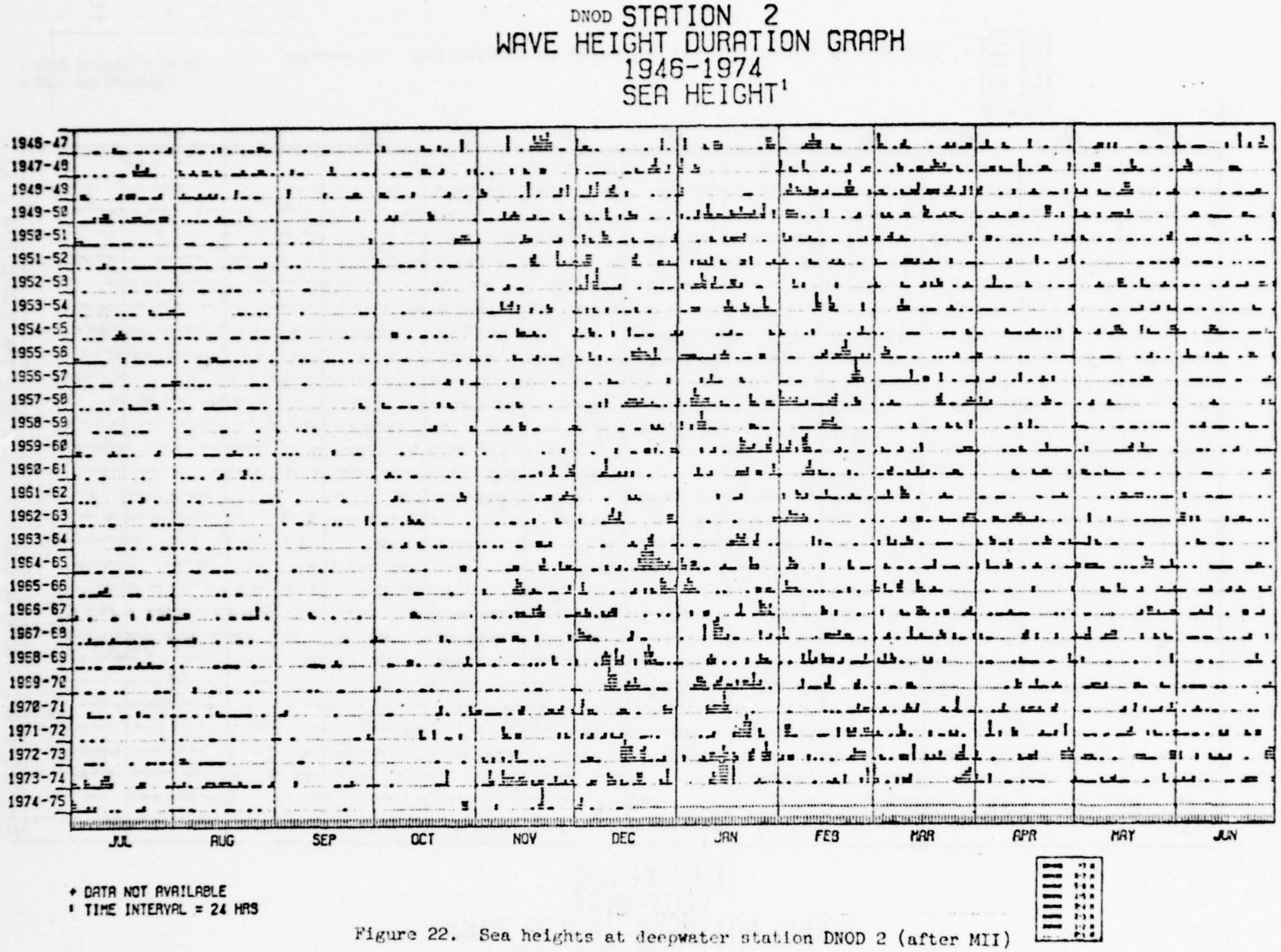


Figure 22. Sea heights at deepwater station DNOD 2 (after MII)

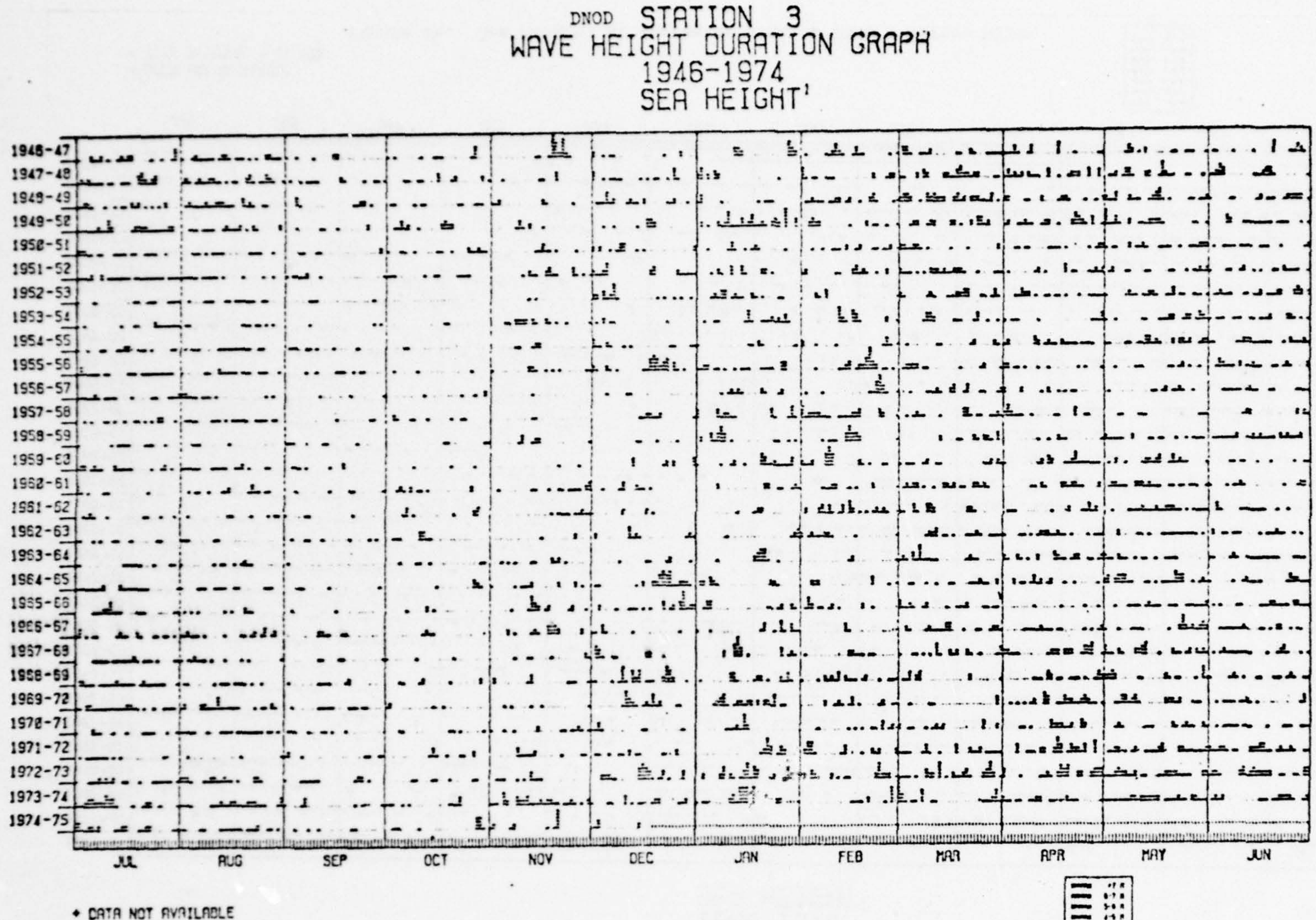
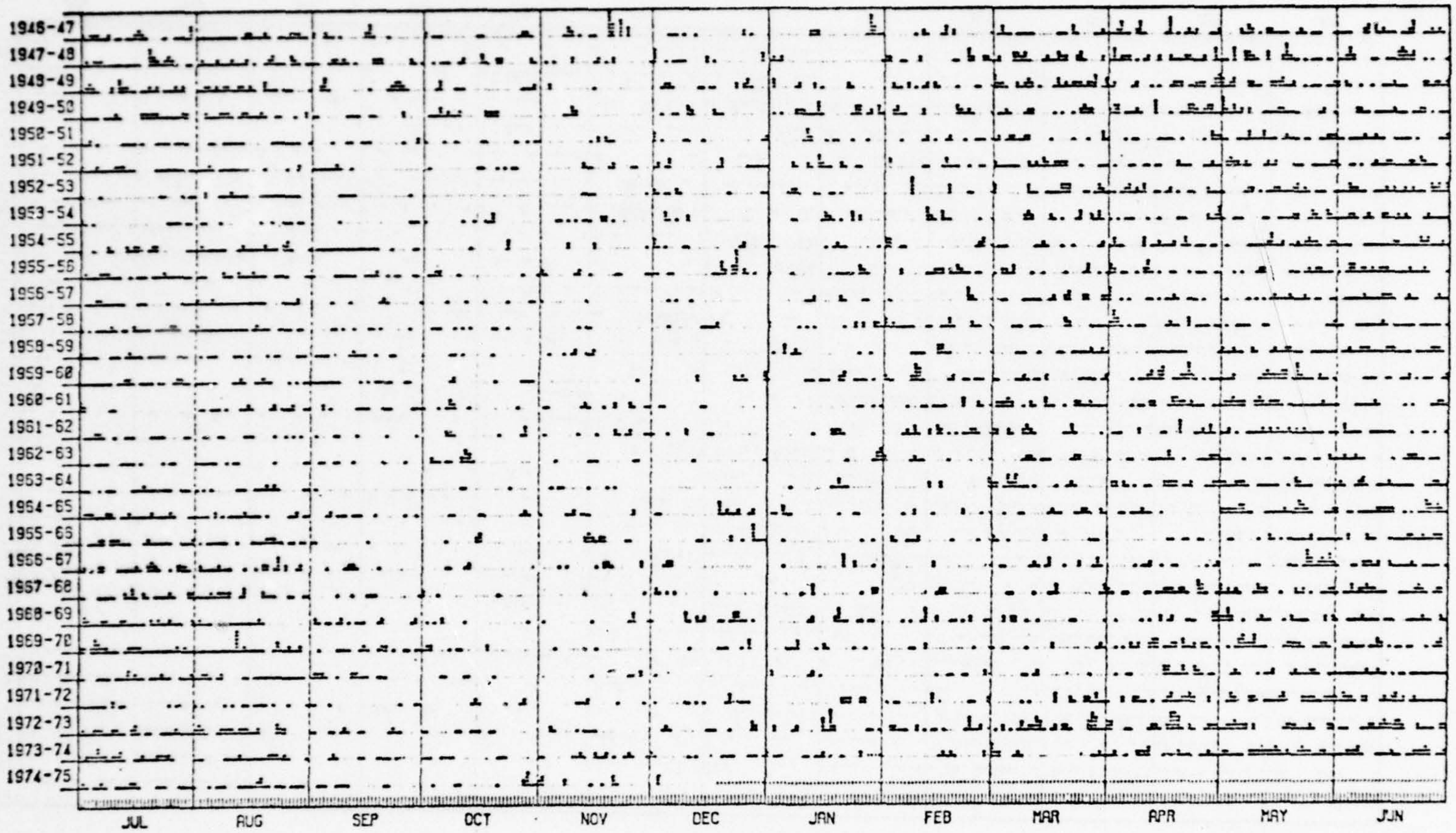


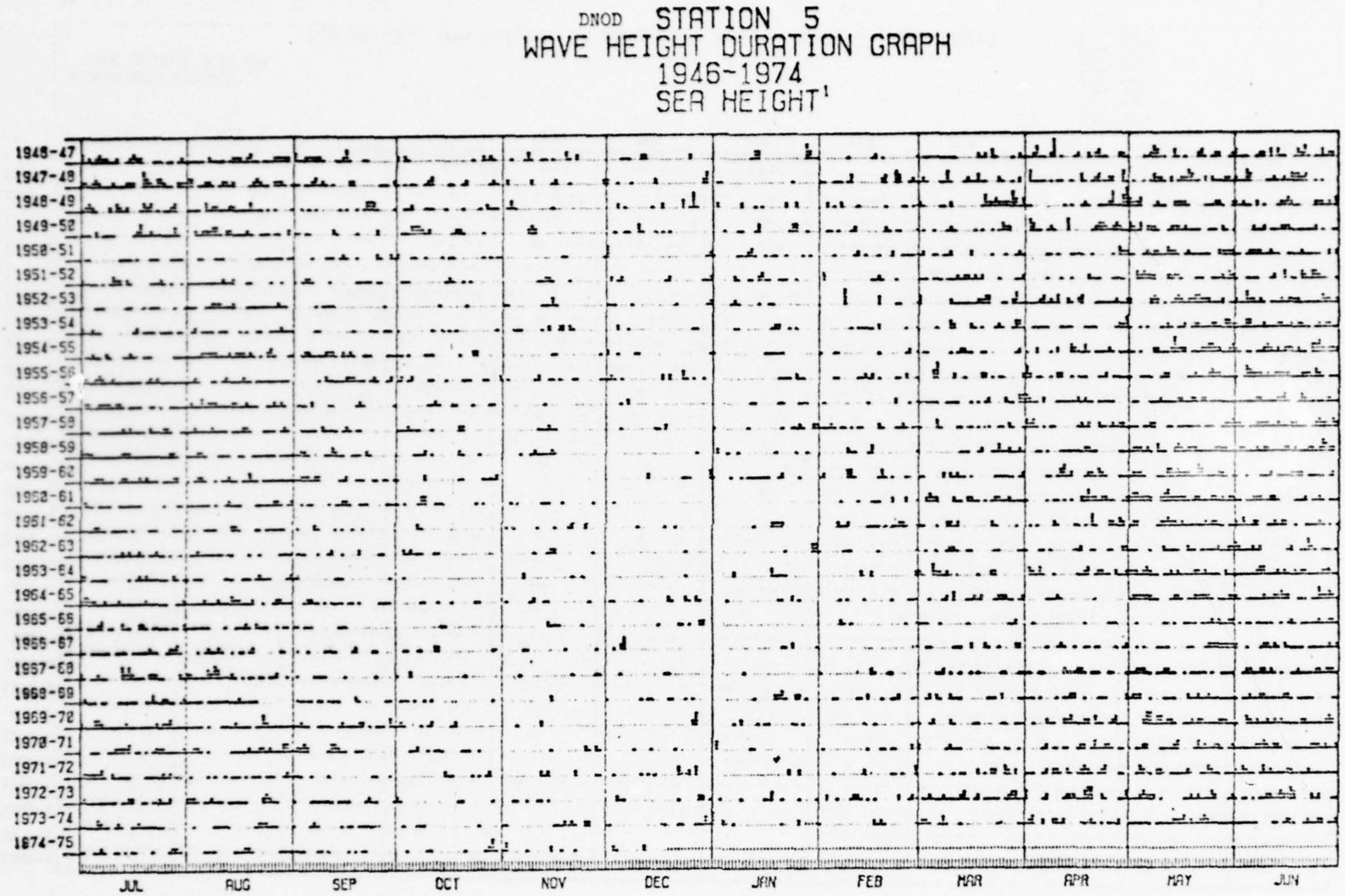
Figure 23. Sea heights at deepwater station DNOD 3 (after MII)

DNOD STATION 4
WAVE HEIGHT DURATION GRAPH
1946-1974
SEA HEIGHT[1]



* DATA NOT AVAILABLE
[1] TIME INTERVAL = 24 HRS

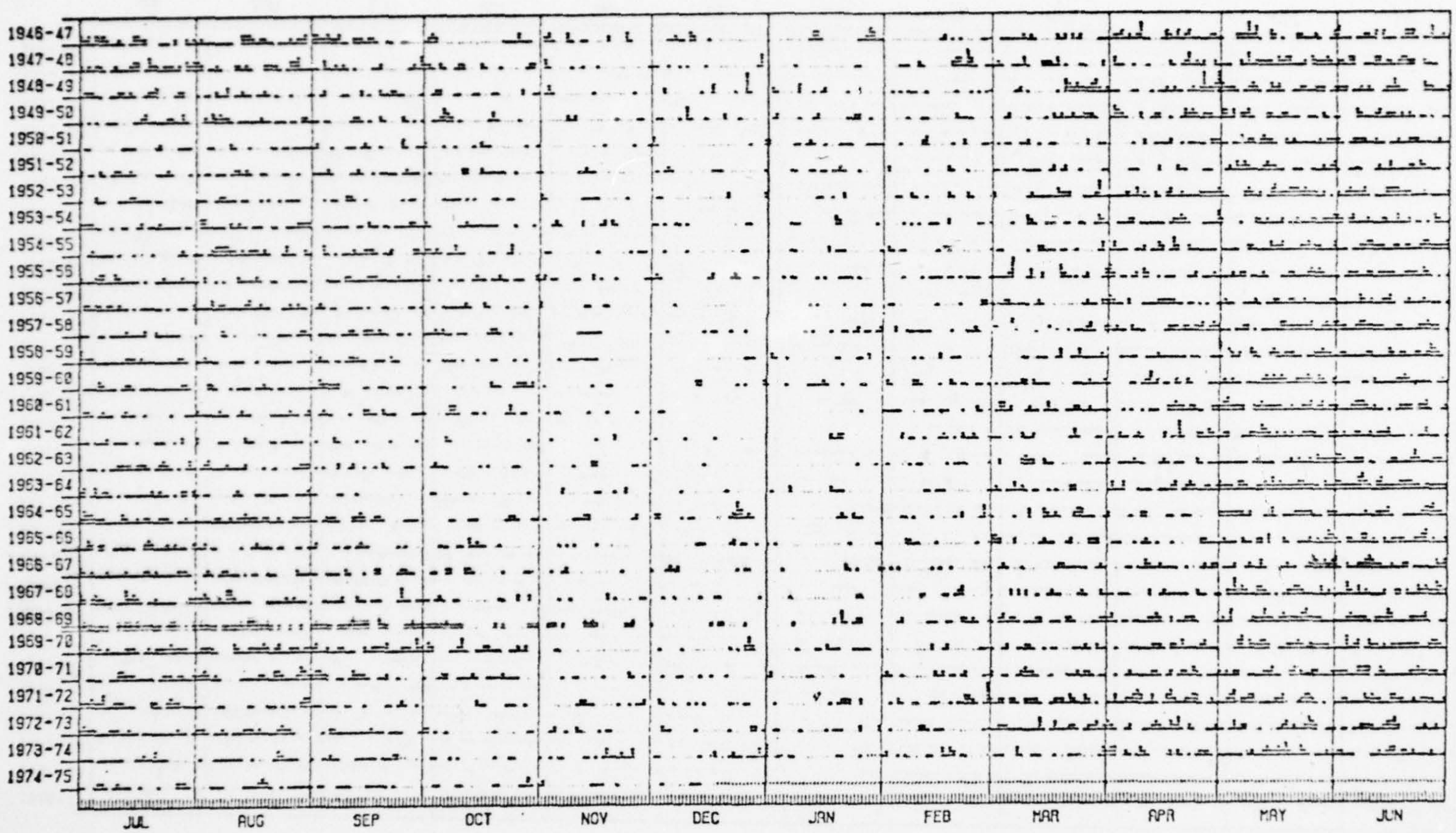
Figure 24. Sea heights at deepwater station DNOD 4 (after MII)

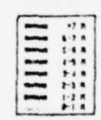


+ DATA NOT AVAILABLE
[1] TIME INTERVAL = 24 HRS

Figure 25. Sea heights at deepwater station DNOD 5 (after MII)

DNOD STATION 6
WAVE HEIGHT DURATION GRAPH
1946-1974
SEA HEIGHT[1]





+ DATA NOT AVAILABLE
' TIME INTERVAL = 24 HRS

Figure 26. Sea heights at deepwater station DNOD 6 (after MII)

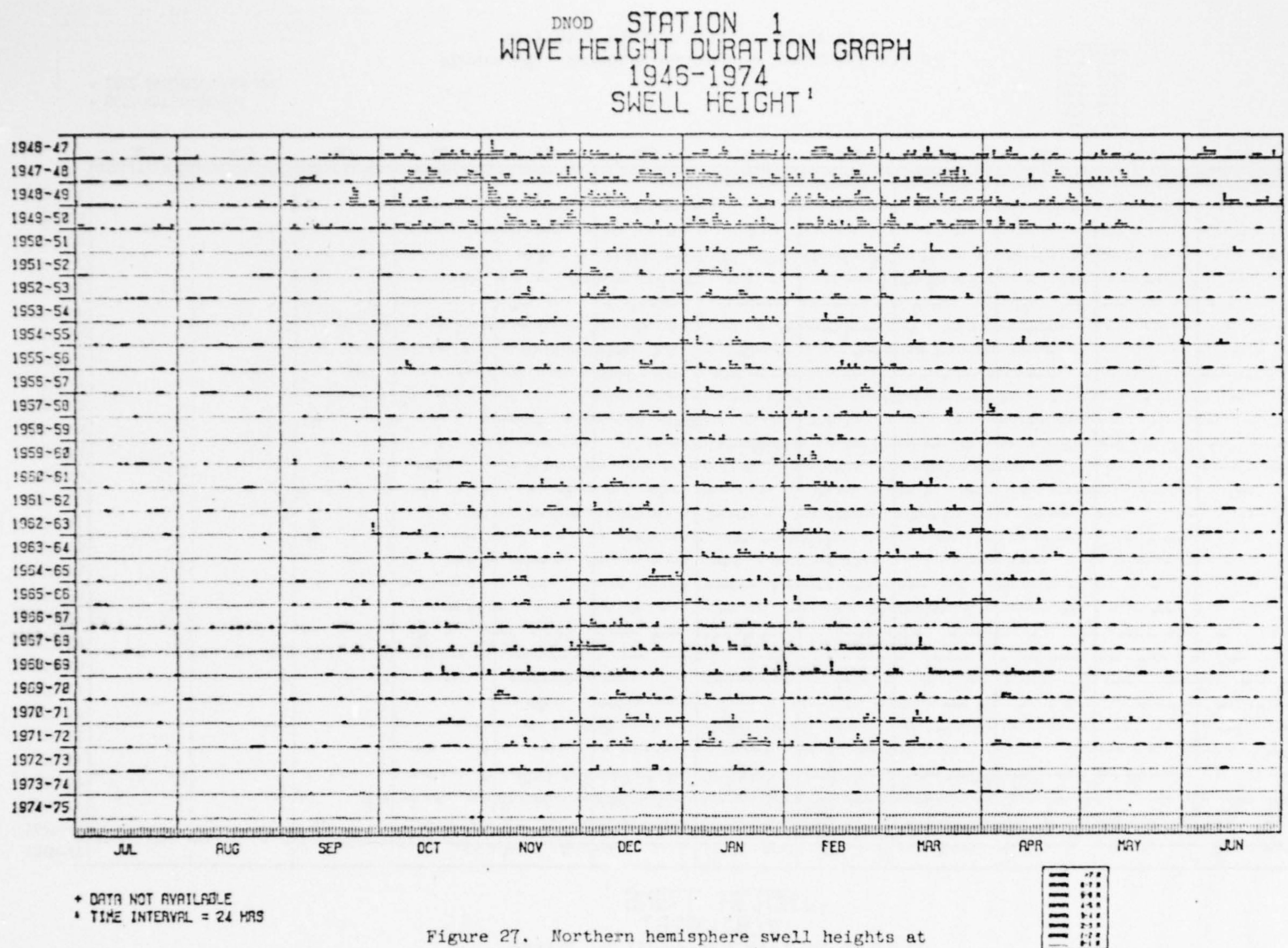


Figure 27. Northern hemisphere swell heights at deepwater station DNOD 1 (after MII)

DNOD STATION 2
WAVE HEIGHT DURATION GRAPH
1946-1974
SWELL HEIGHT[1]

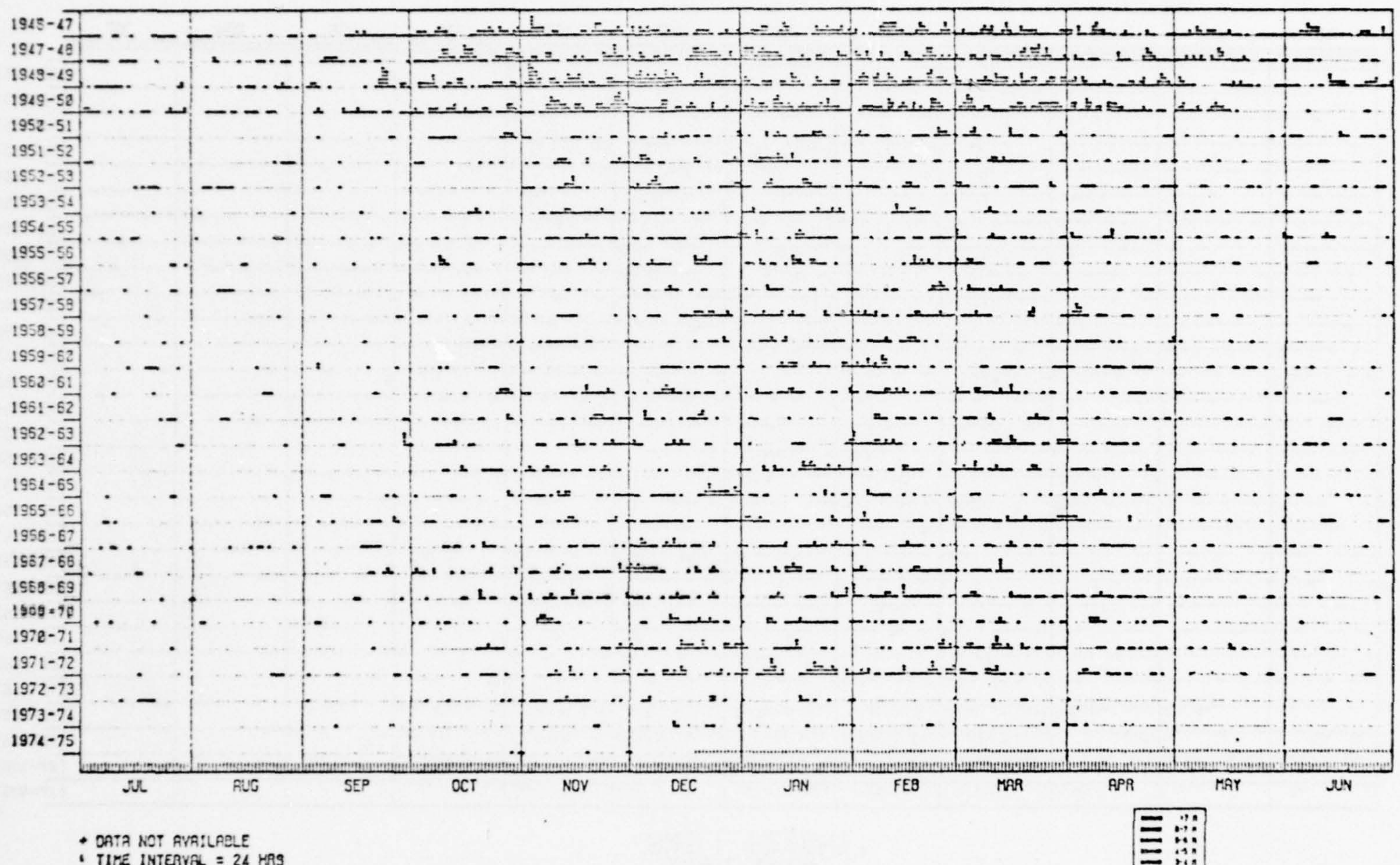
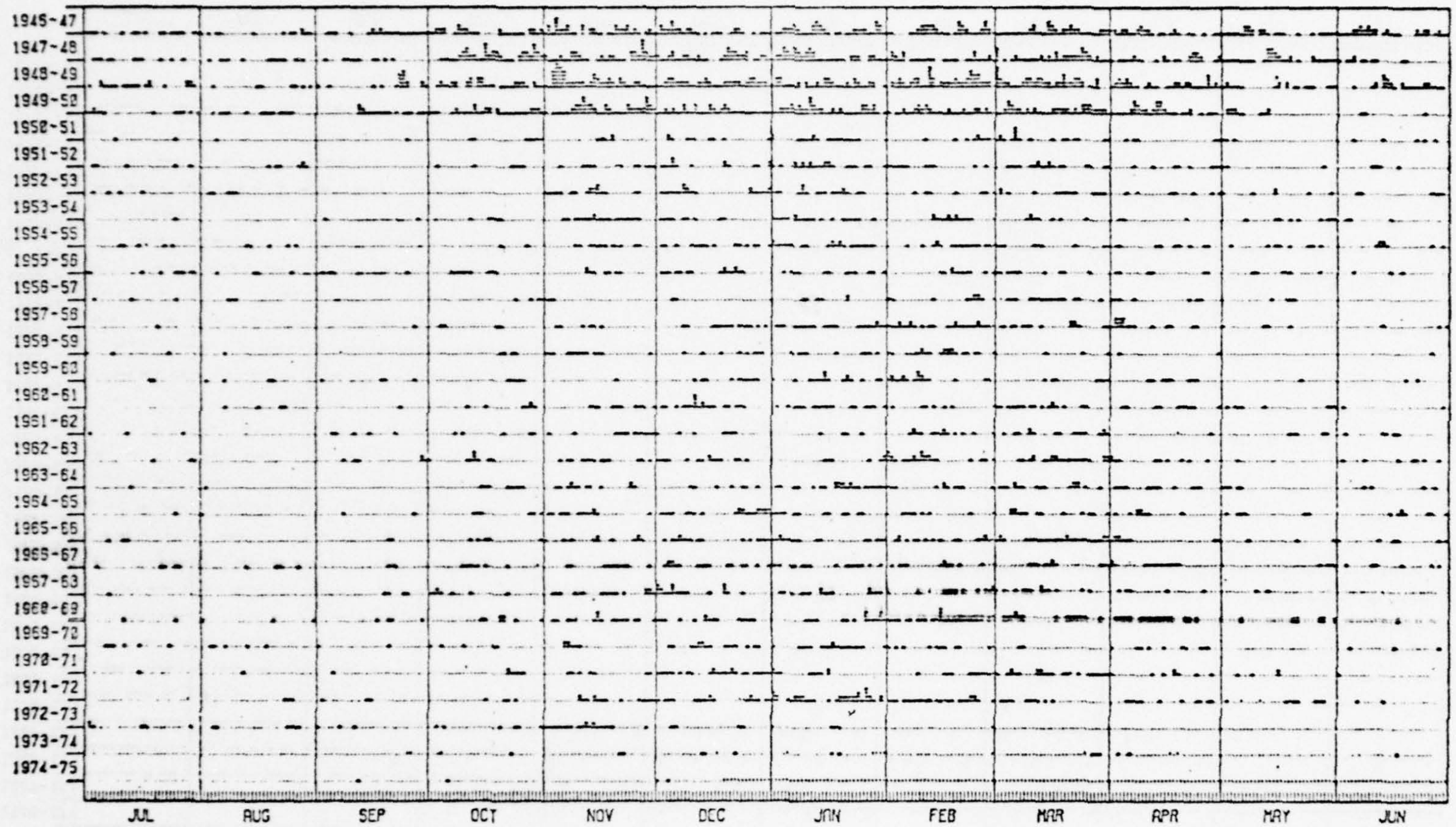


Figure 28. Northern hemisphere swell heights at deepwater station DNOD 2 (after MI1)

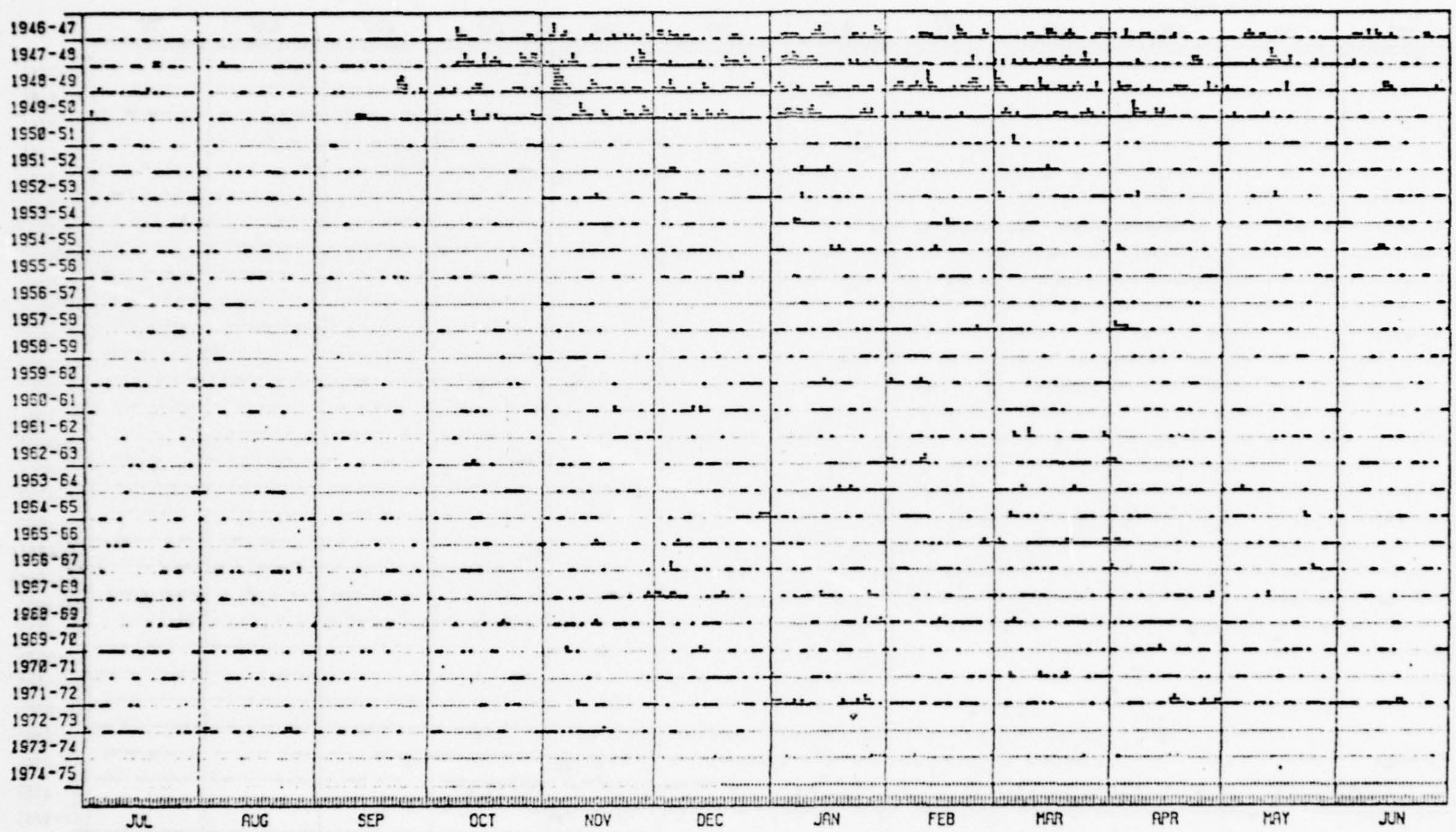
DNOD STATION 3
WAVE HEIGHT DURATION GRAPH
1946-1974
SWELL HEIGHT[1]



+ DATA NOT AVAILABLE
1 TIME INTERVAL = 24 HRS

Figure 29. Northern hemisphere swell heights at deepwater station DNOD 3 (after MII)

DNOD STATION 4
WAVE HEIGHT DURATION GRAPH
1946-1974
SWELL HEIGHT[1]



+ DATA NOT AVAILABLE
[1] TIME INTERVAL = 24 HRS

Figure 30. Northern hemisphere swell heights at deepwater station DNOD 4 (after MII)

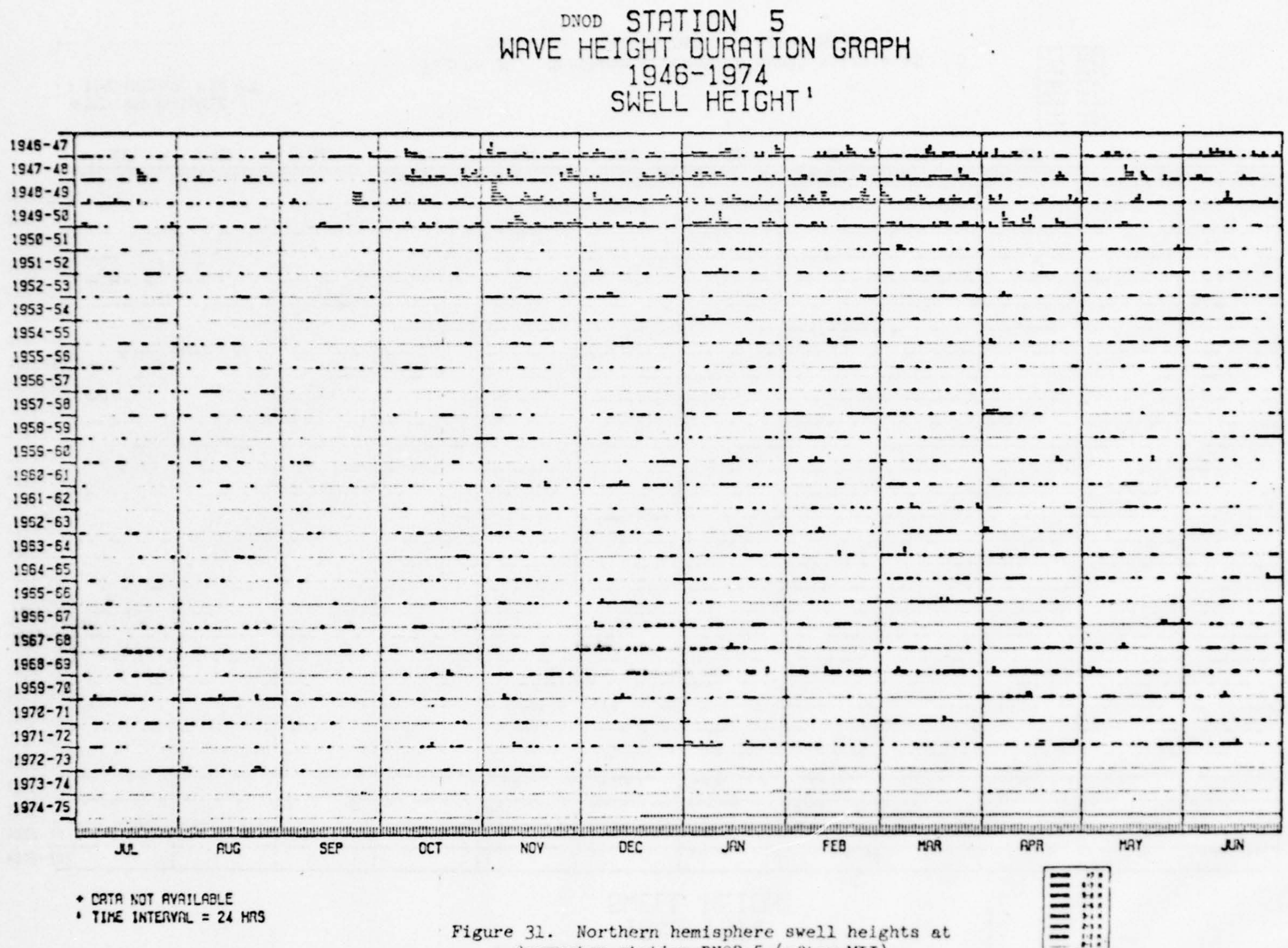


Figure 31. Northern hemisphere swell heights at deepwater station DNOD 5 (after MII)

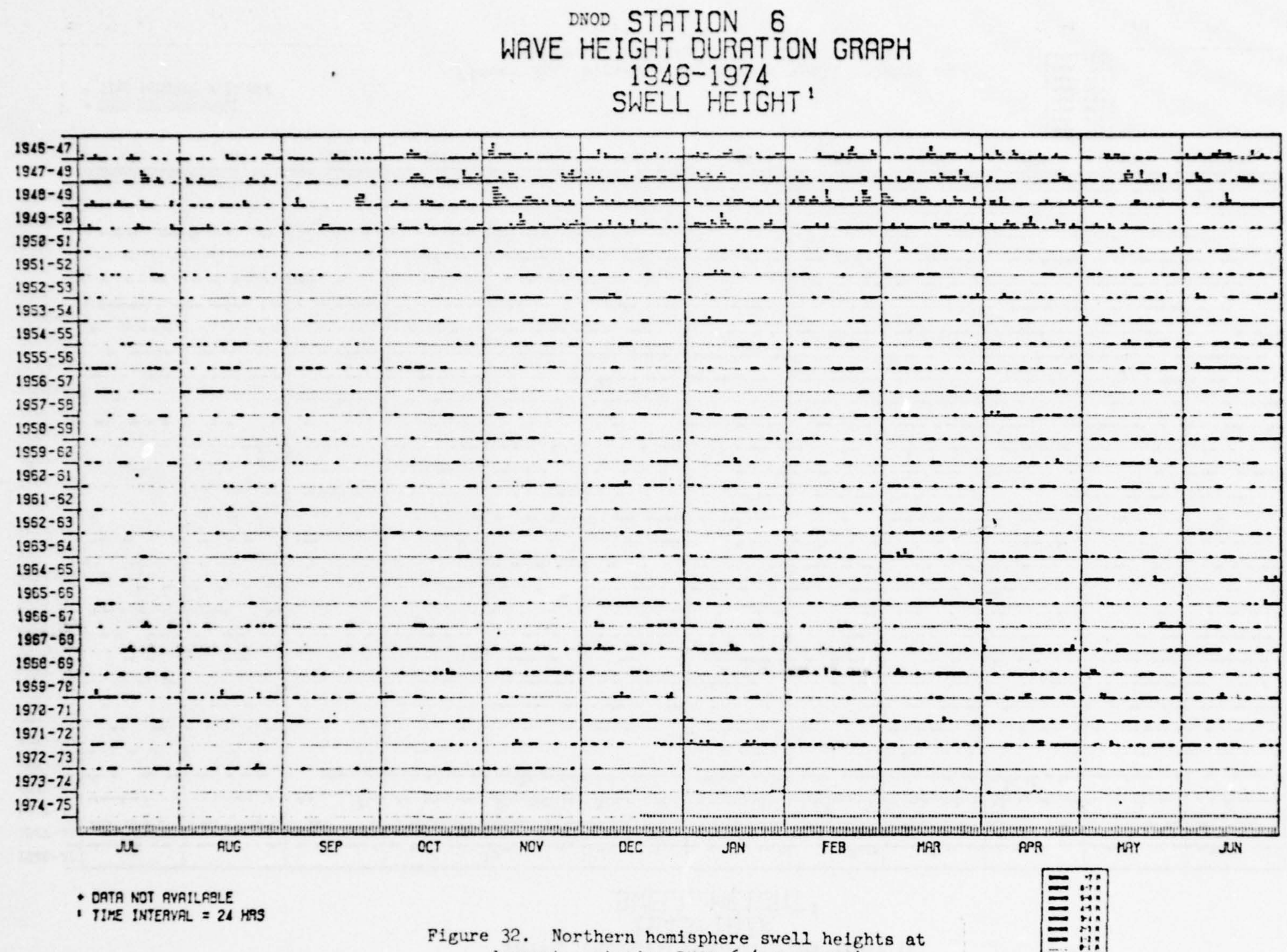


Figure 32. Northern hemisphere swell heights at deepwater station DNOD 6 (after MII)

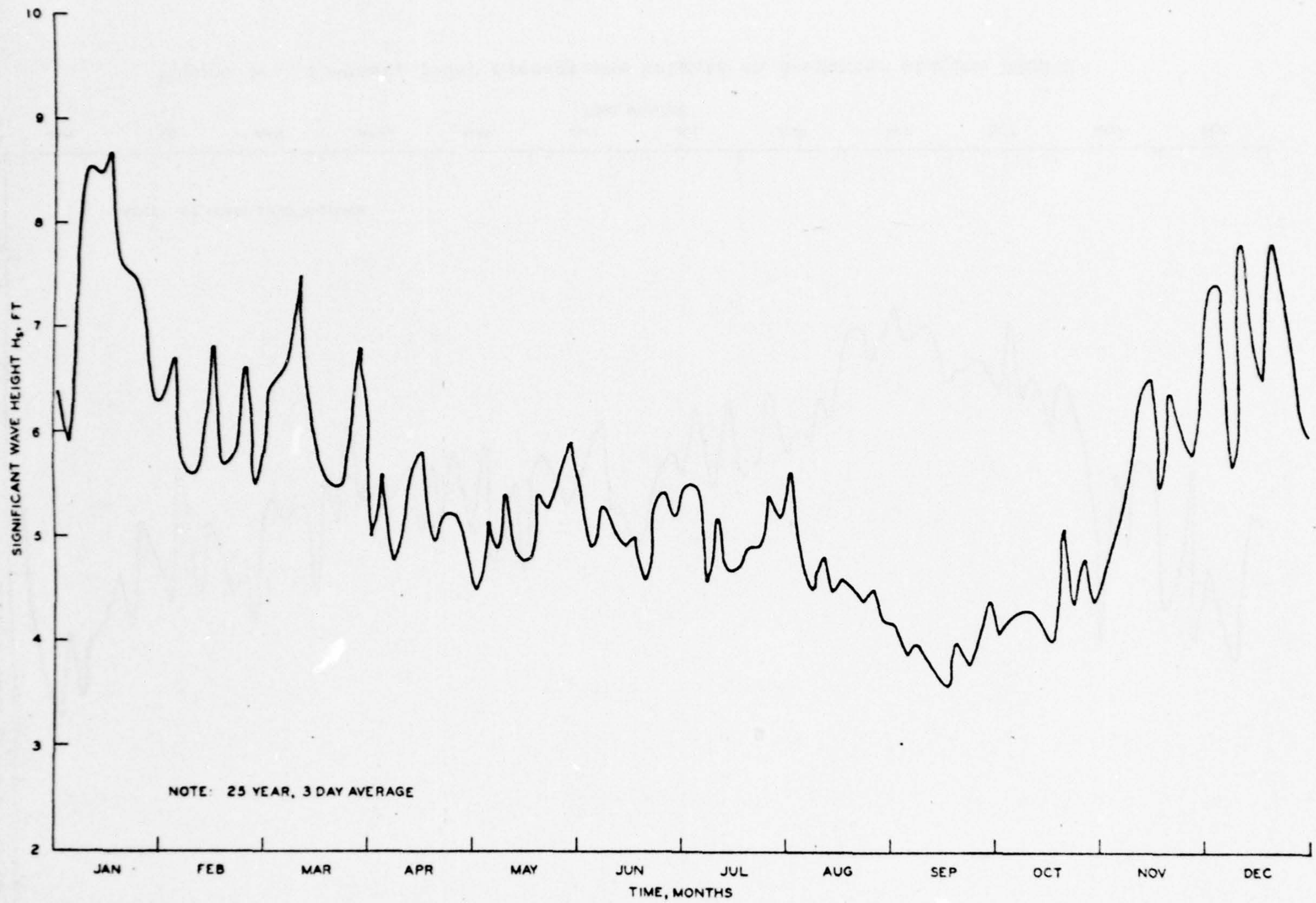


Figure 33. 25-year, 3-day average sea heights at deepwater station DNOD 1

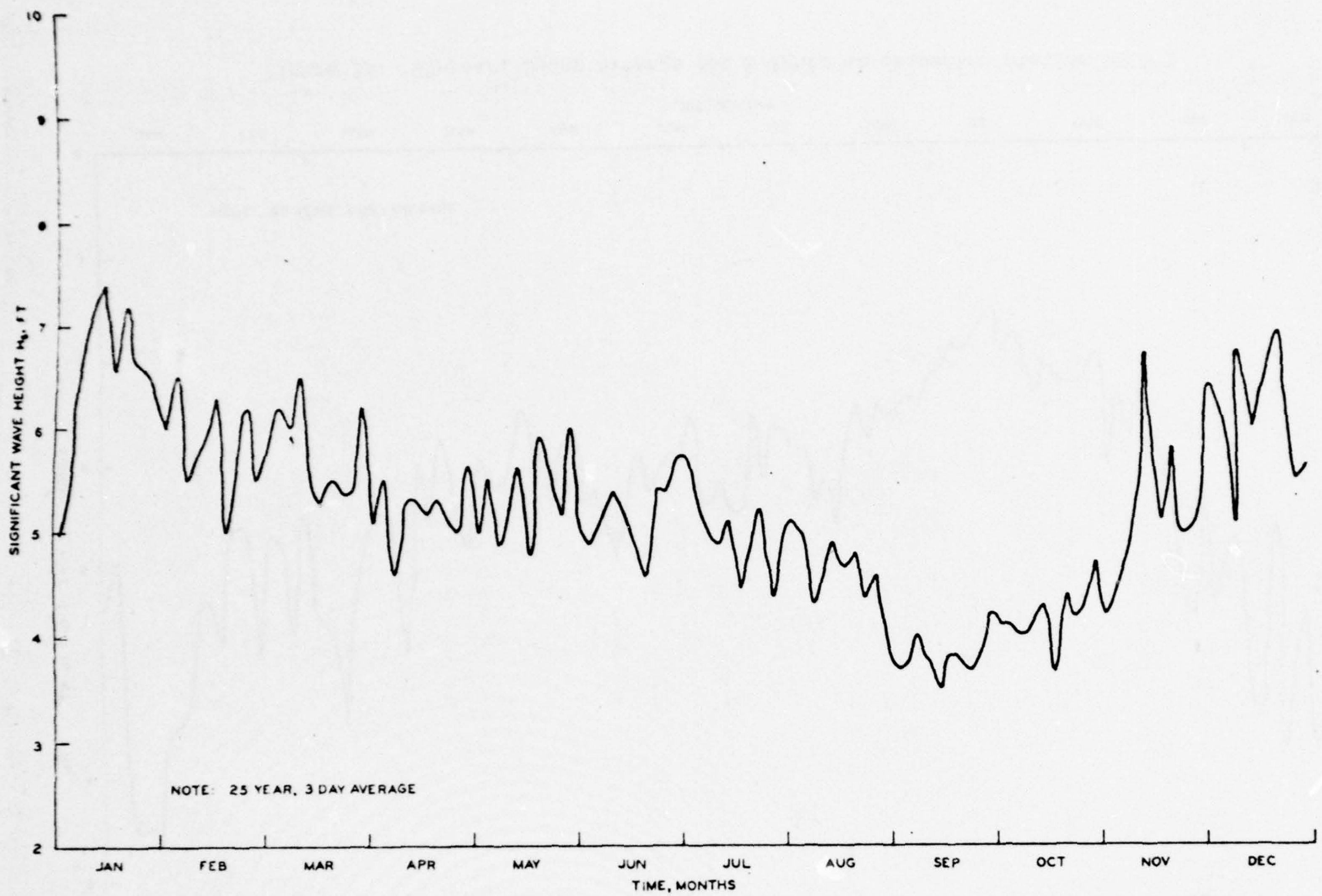


Figure 34. 25-year, 3-day average sea heights at deepwater station DNOD 2

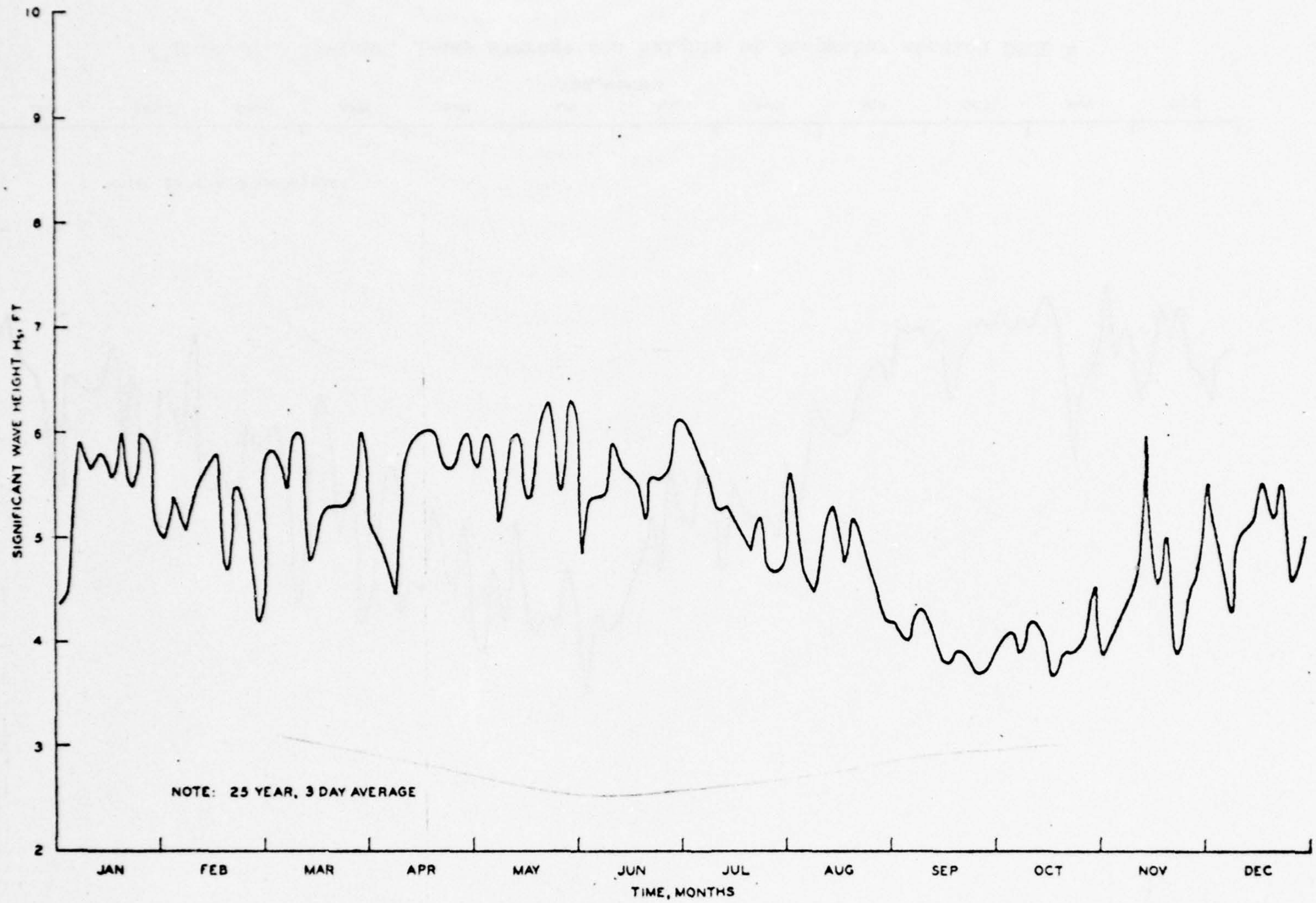


Figure 35. 25-year, 3-day average sea heights at deepwater station DNOD 3

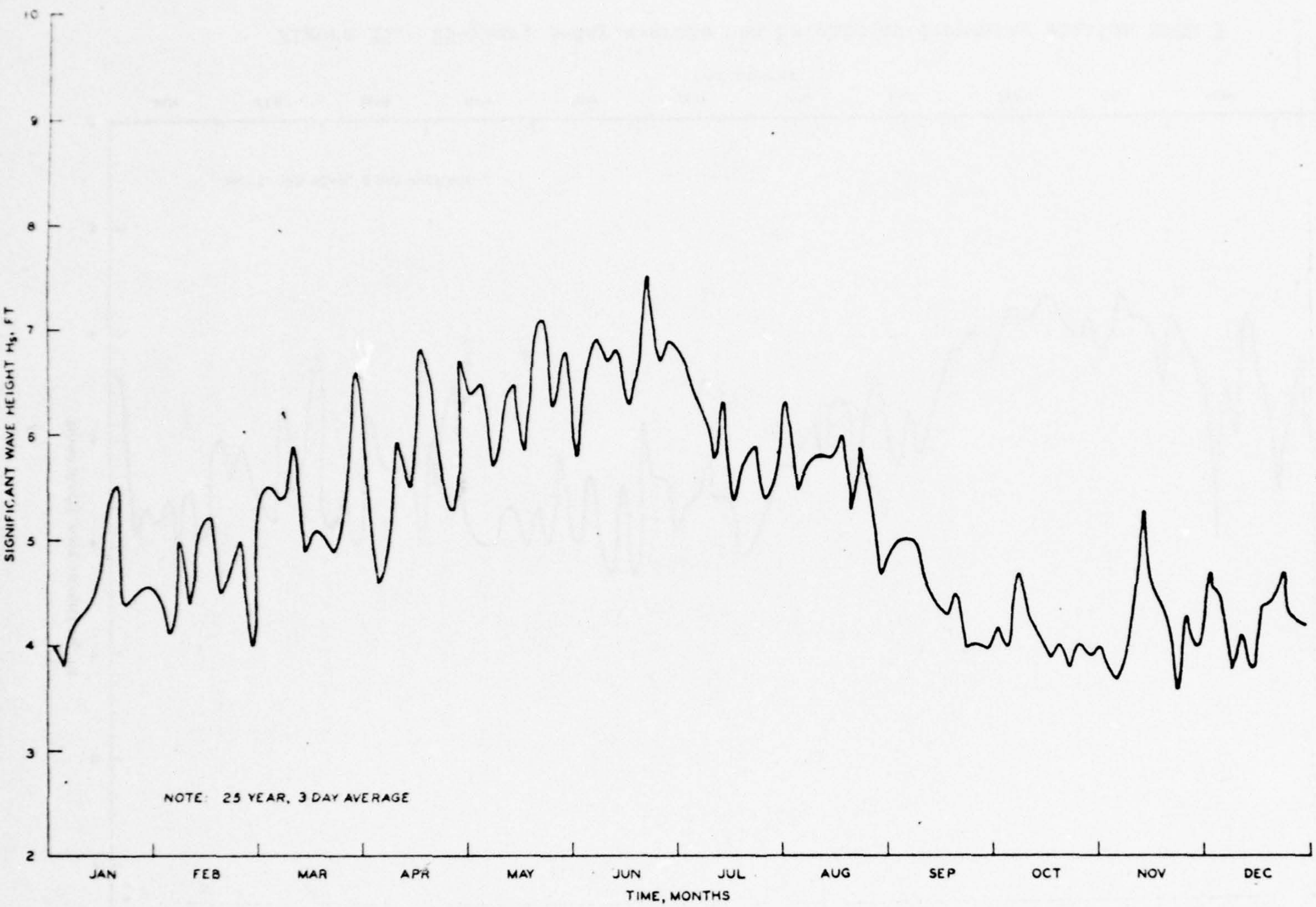


Figure 36. 25-year, 3-day average sea heights at deepwater station DNOD 4

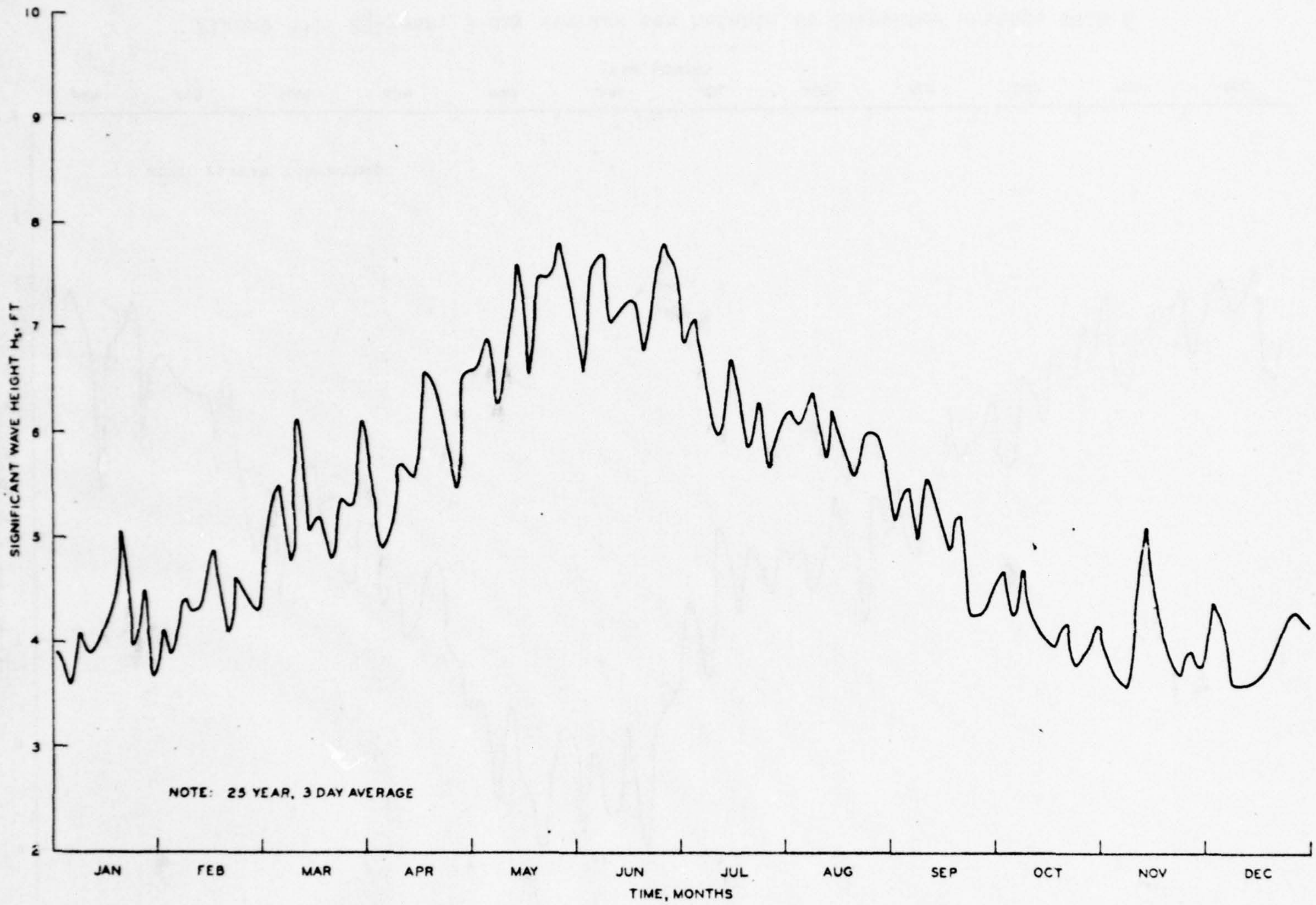


Figure 37. 25-year, 3-day average sea heights at deepwater station DNOD 5

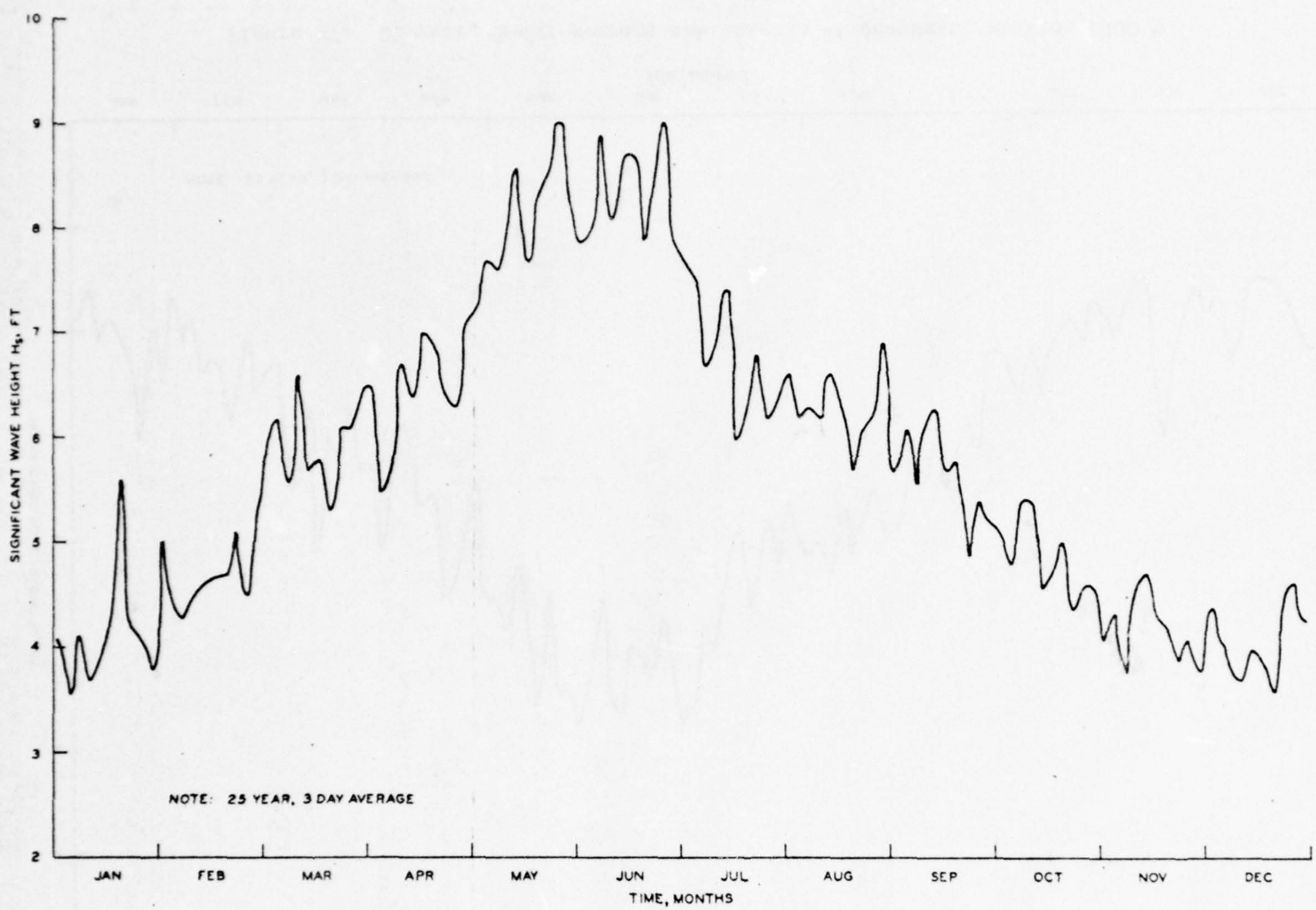


Figure 38. 25-year, 3-day average sea heights at deepwater station DNOD 6

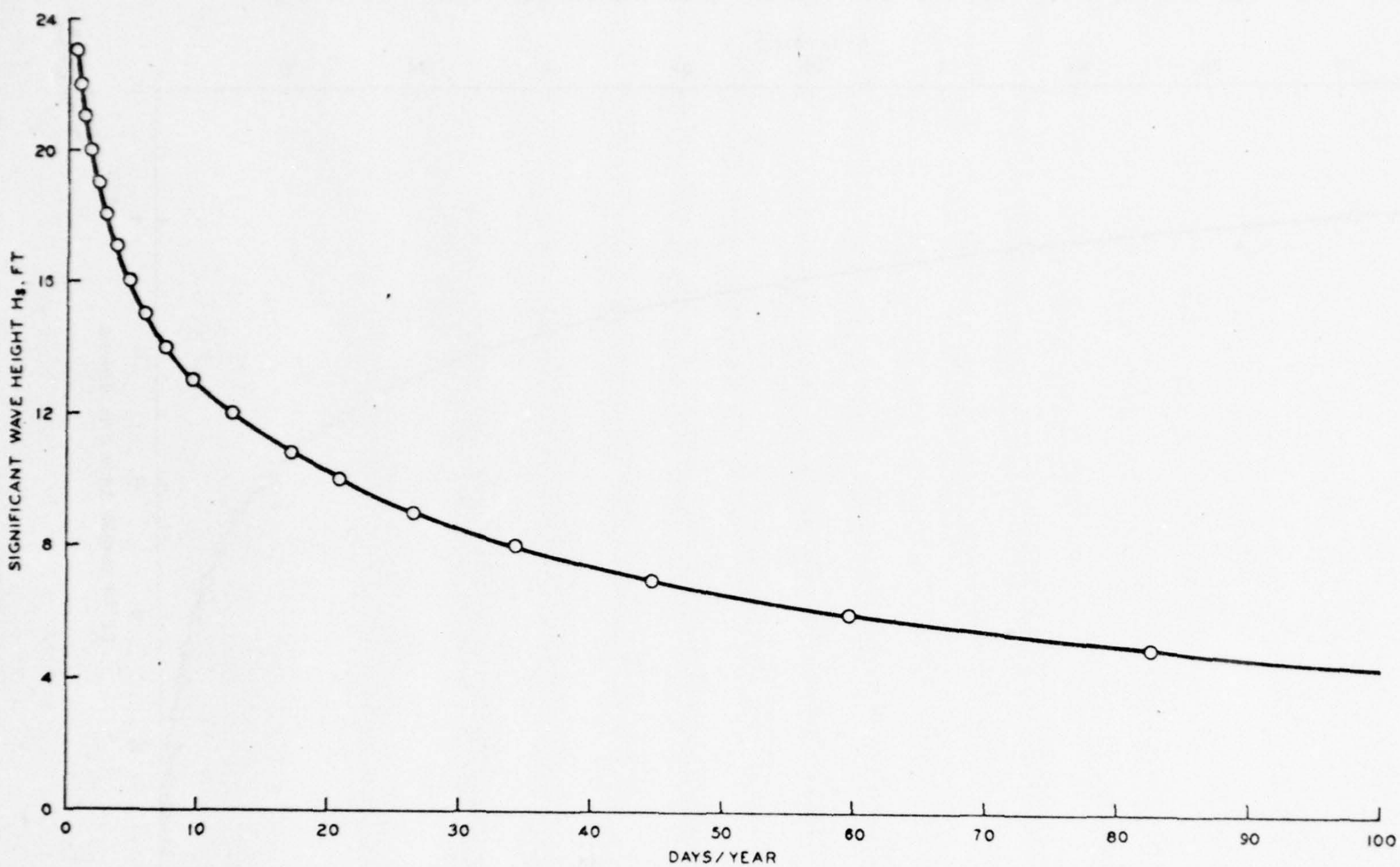


Figure 39. Days/year waves exceed specific wave heights, Crescent City LNG site

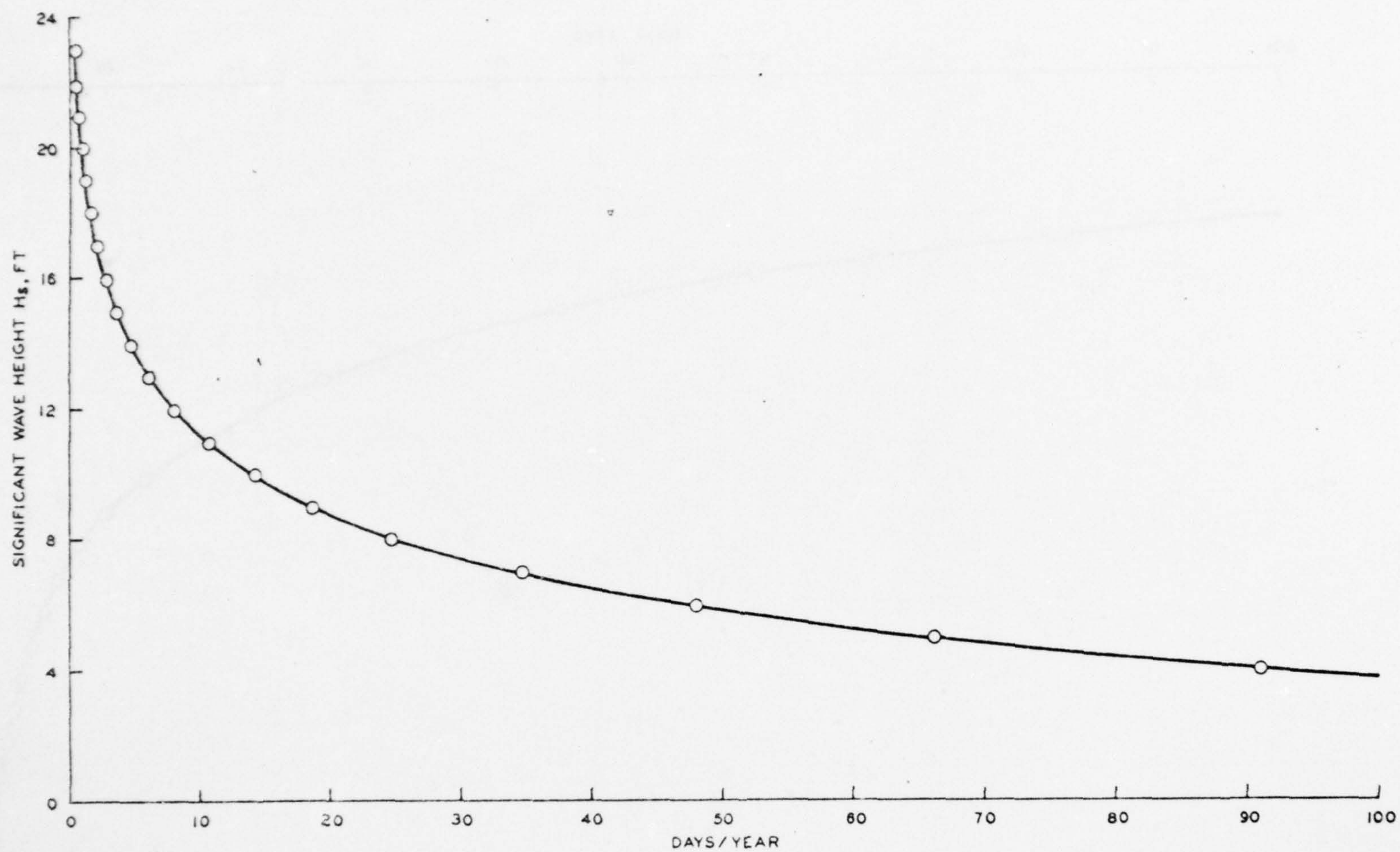


Figure 40. Days/year waves exceed specific wave heights, Point Delgada LNG site

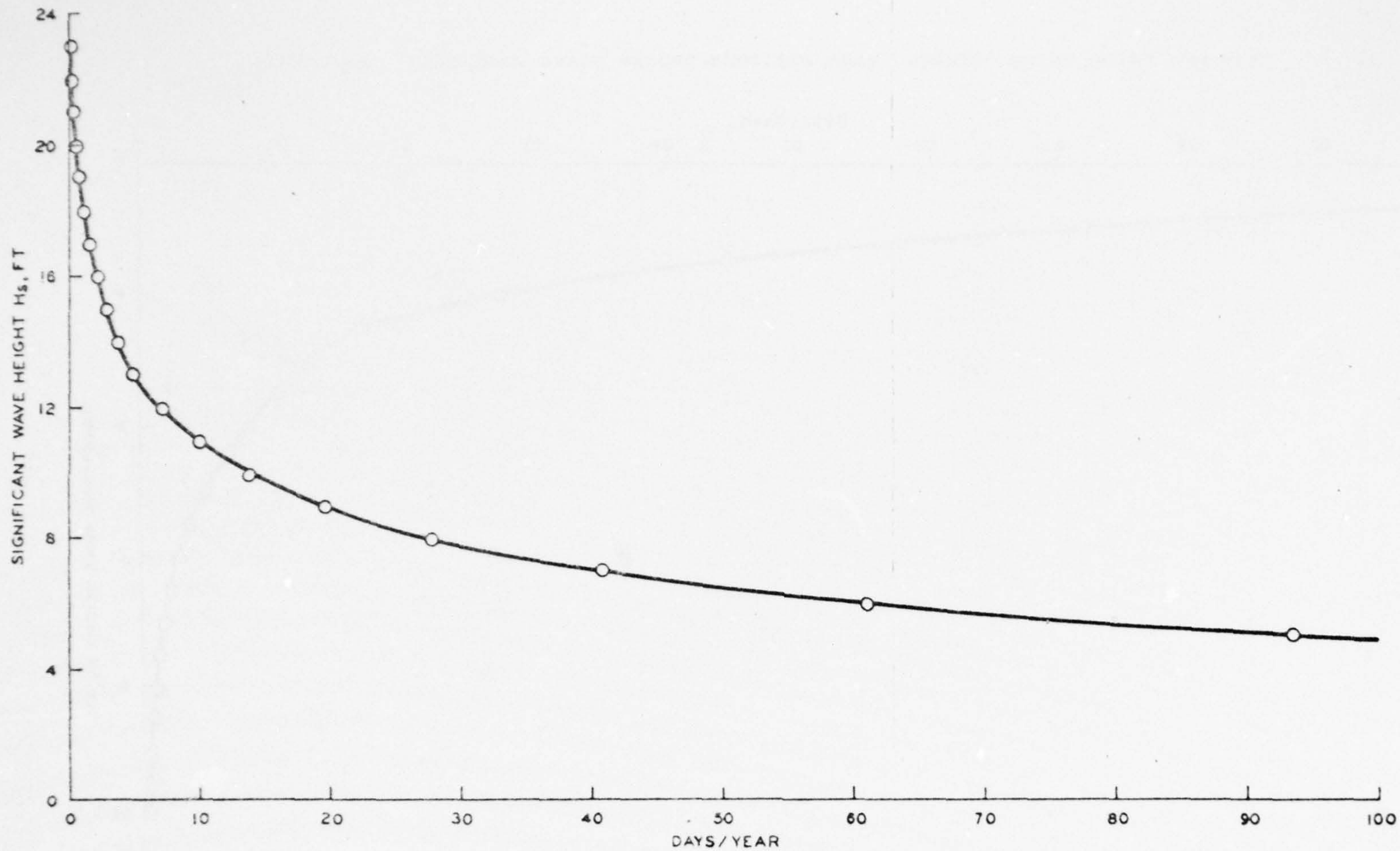


Figure 41. Days/year waves exceed specific wave heights, Point Arena LNG site

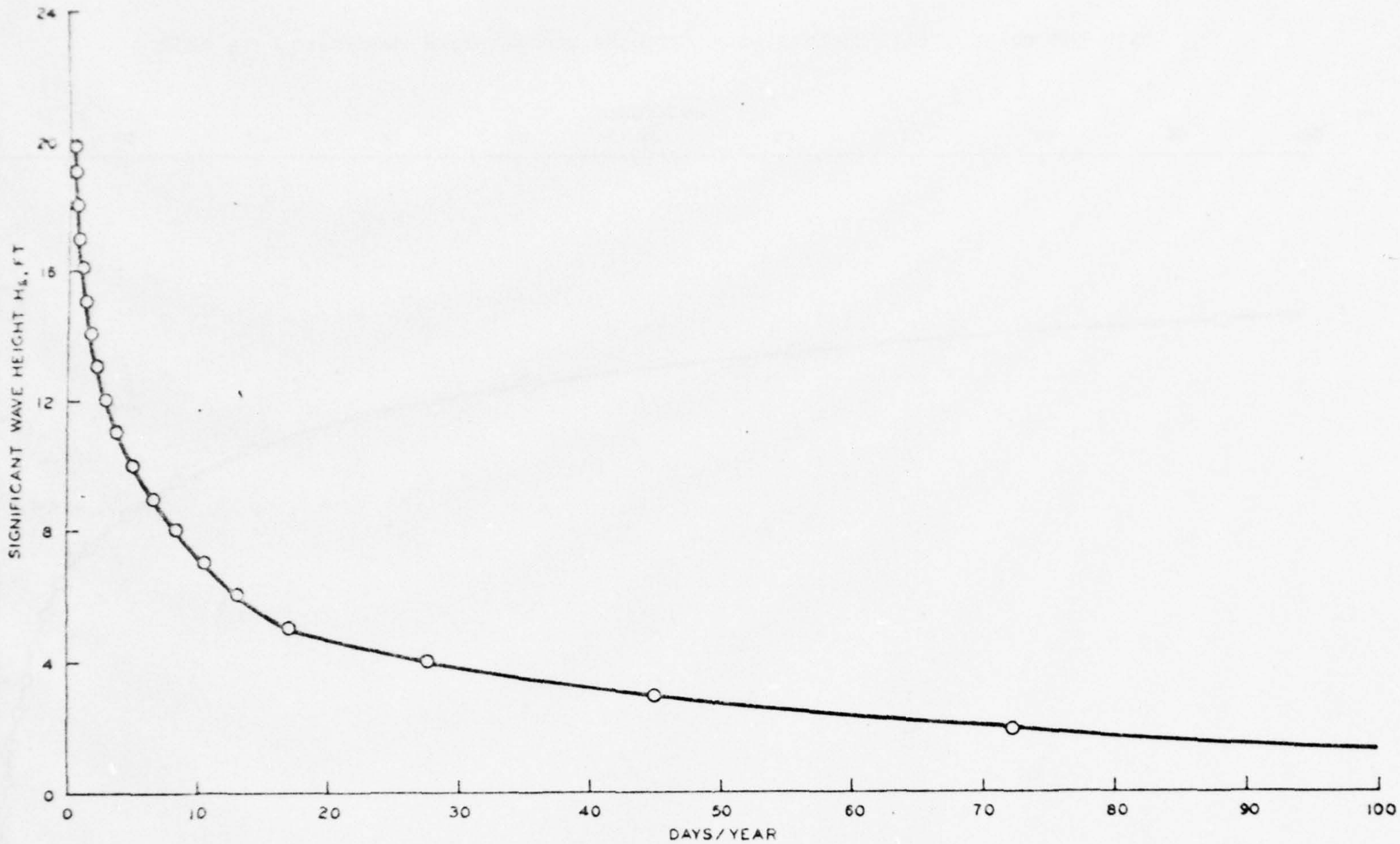


Figure 42. Days/year waves exceed specific wave heights, Point Reyes LNG site

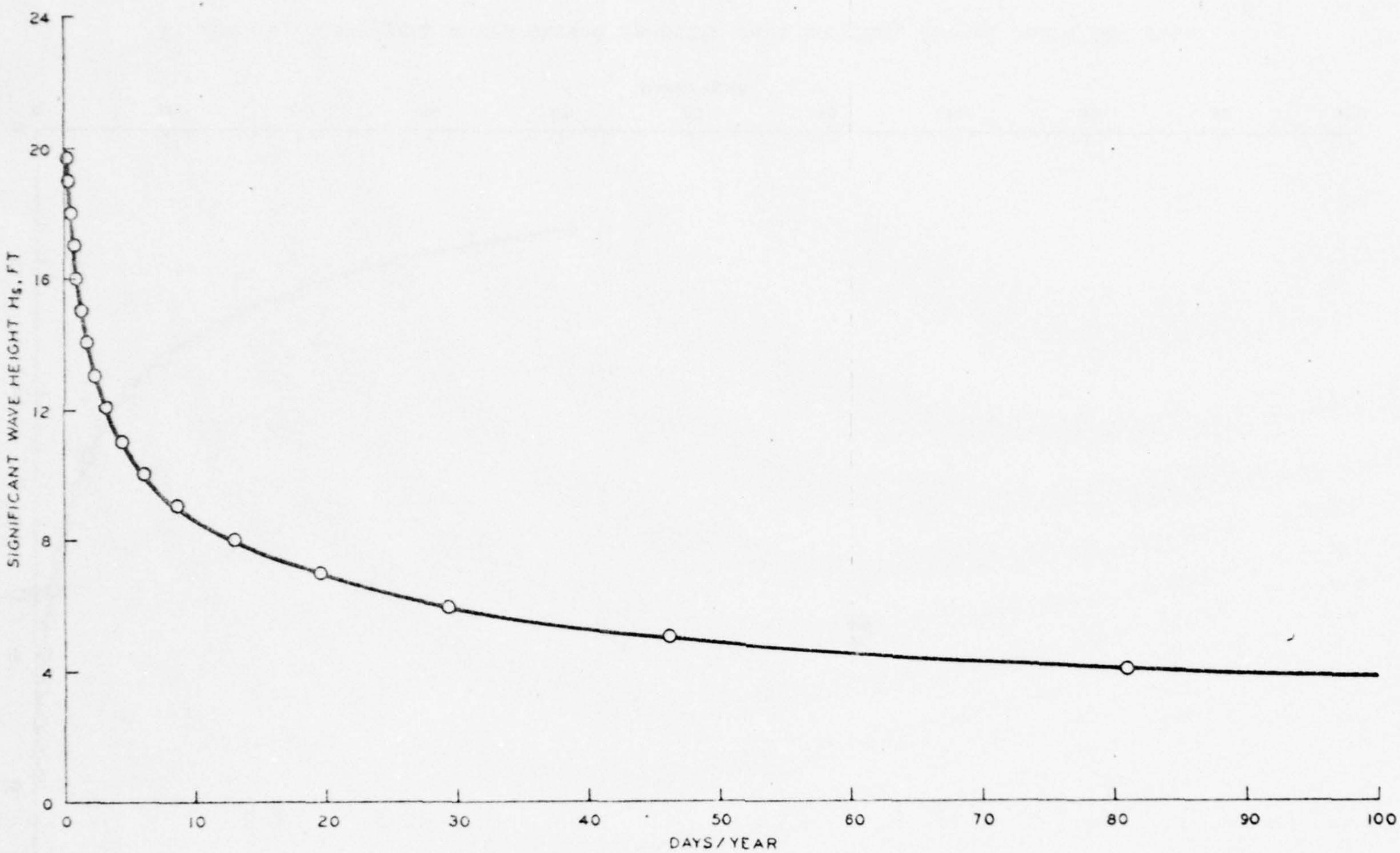


Figure 43. Days/year waves exceed specific wave heights, Davenport LNG site

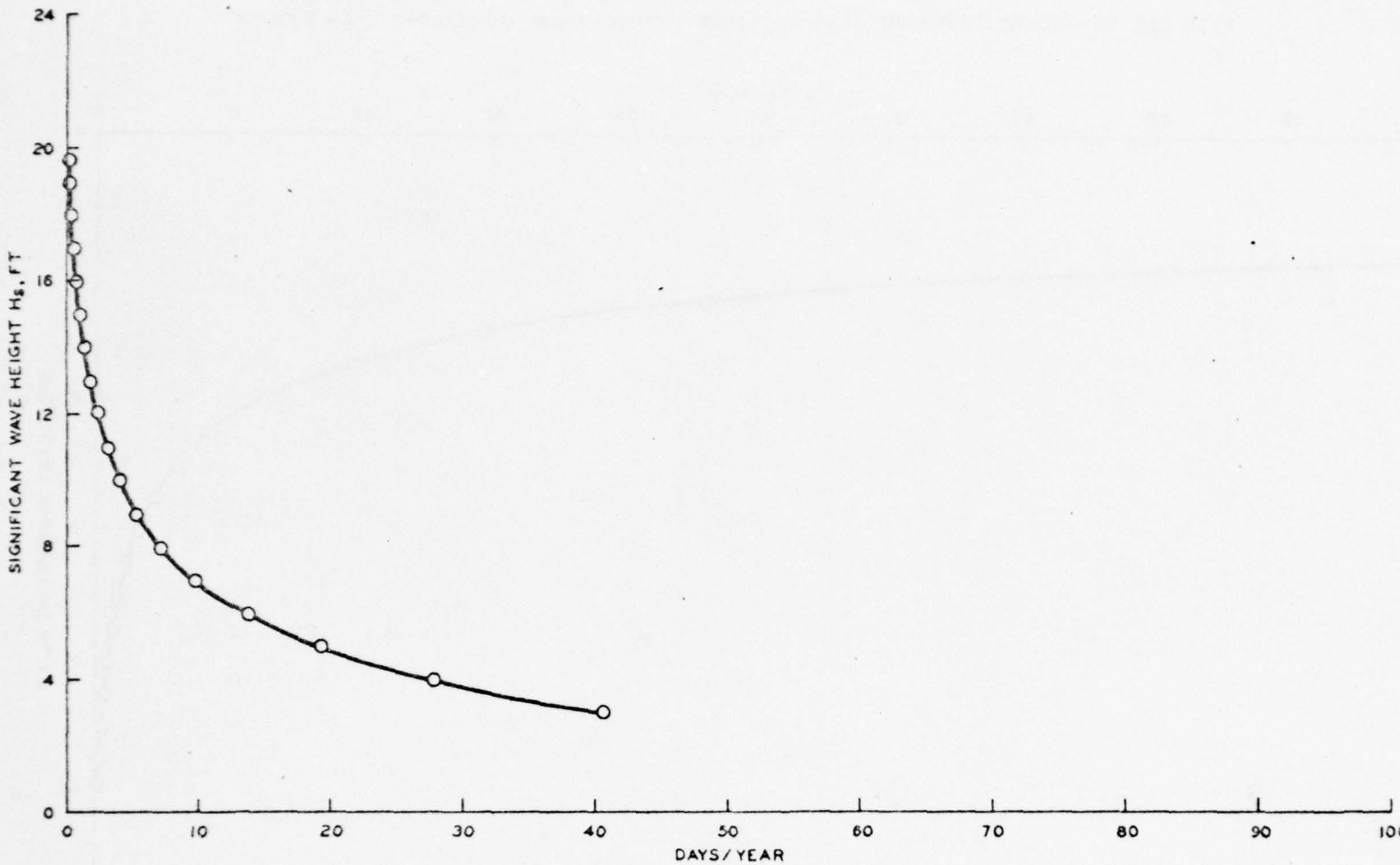


Figure 44. Days/year waves exceed specific wave heights, Soquel Point LNG site

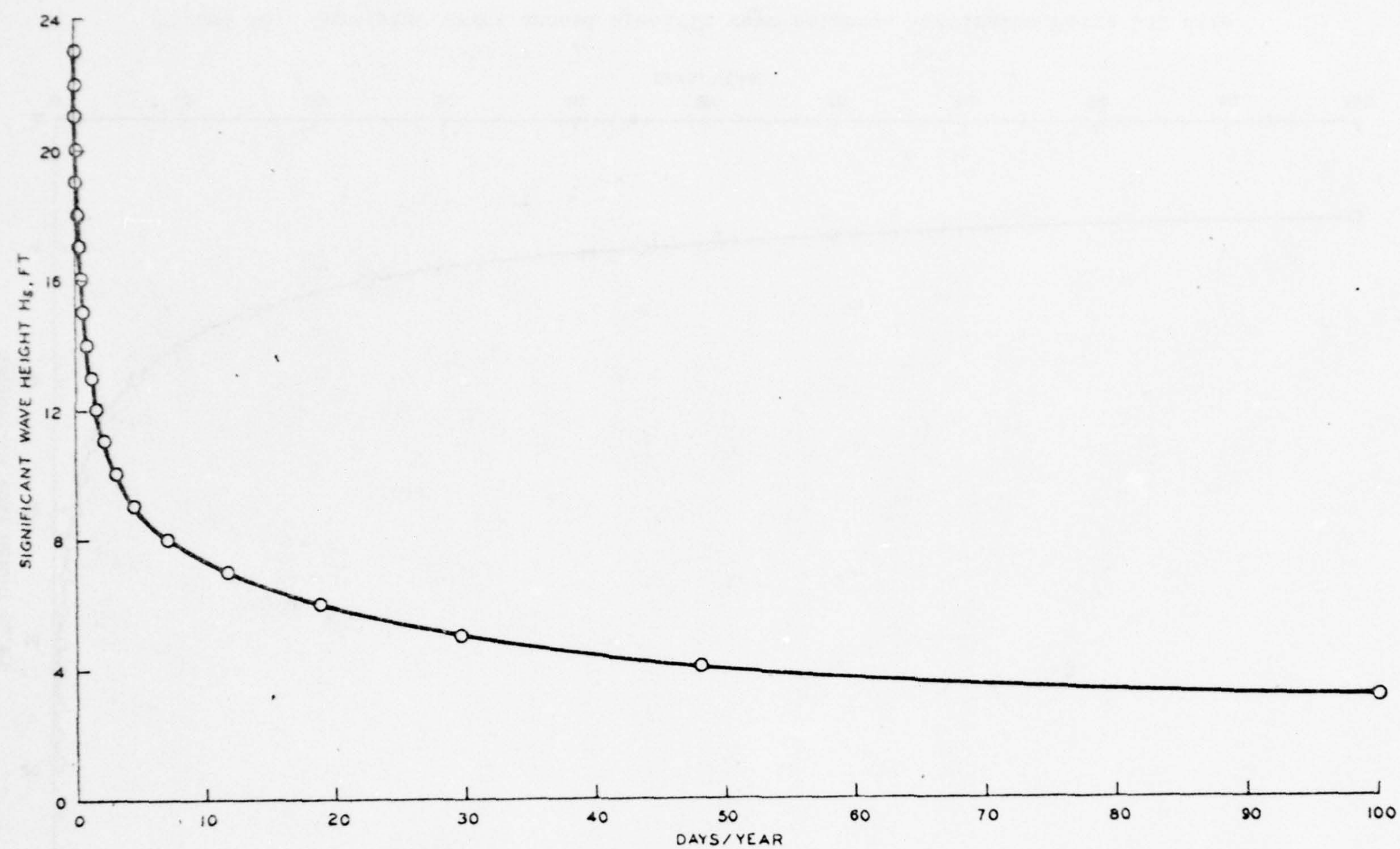


Figure 45. Days/year waves exceed specific wave heights, Moss Landing LNG site

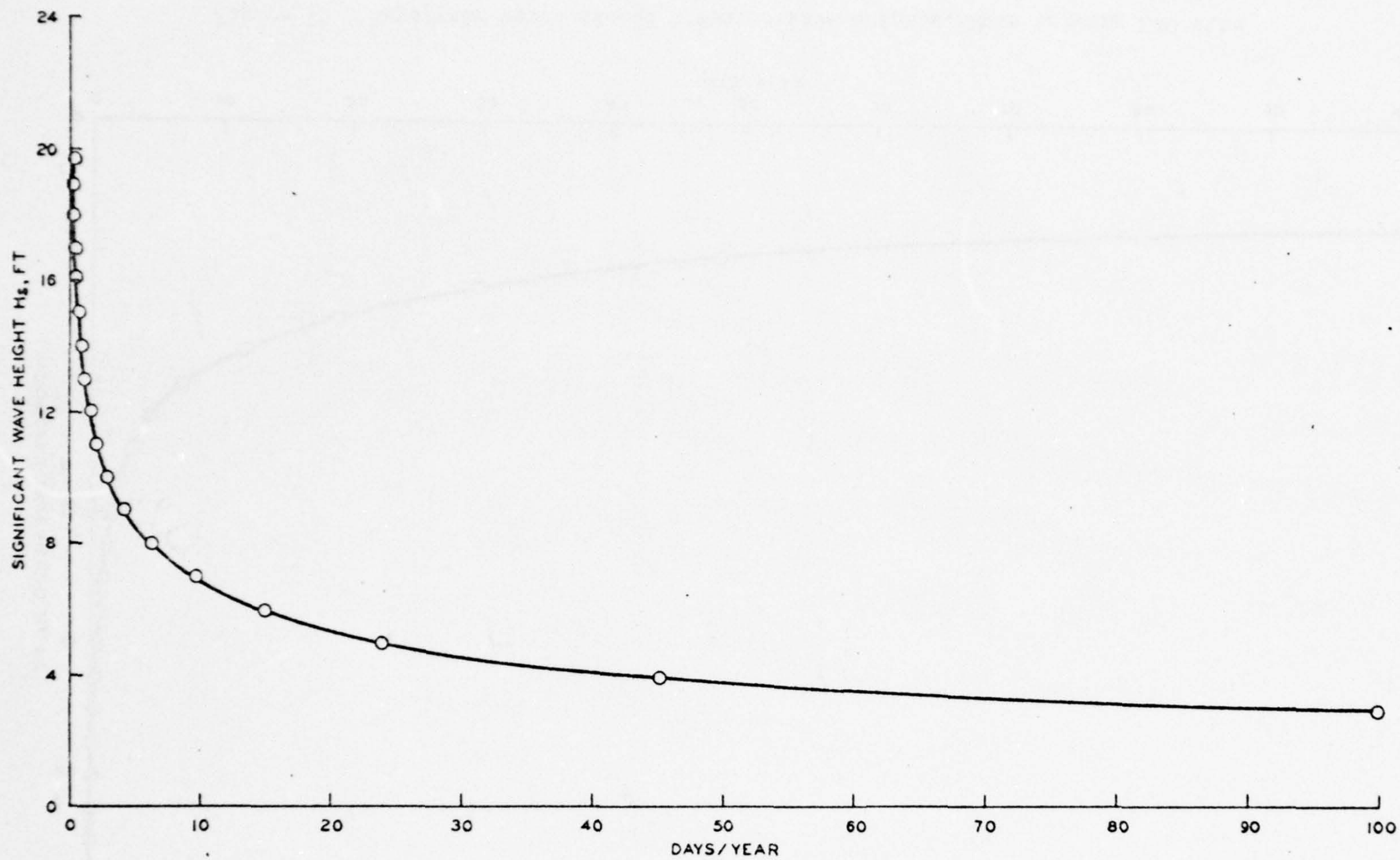


Figure 46. Days/year waves exceed specific wave heights, Partington Point LNG site

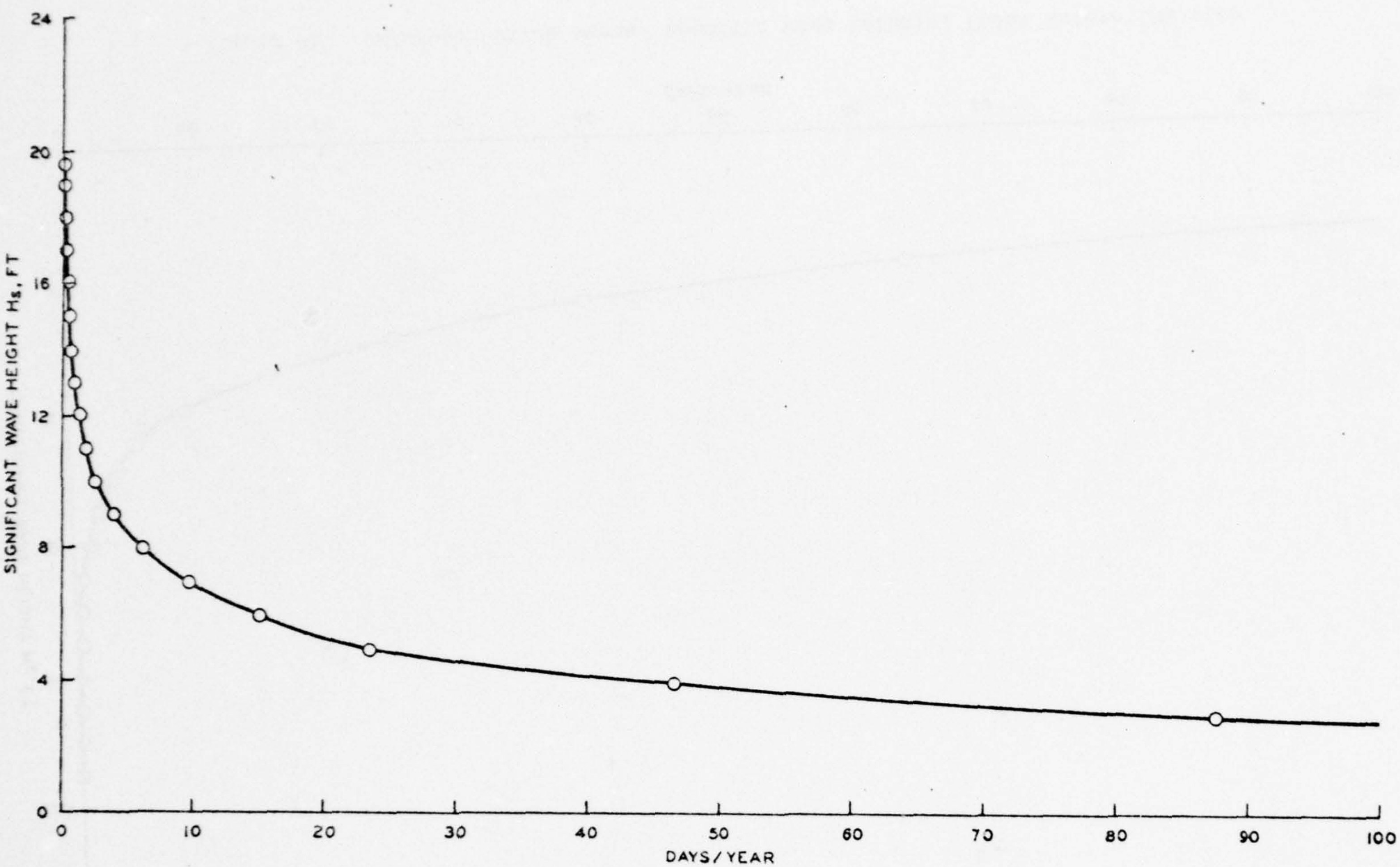


Figure 47. Days/year waves exceed specific wave heights, San Simeon Point LNG site

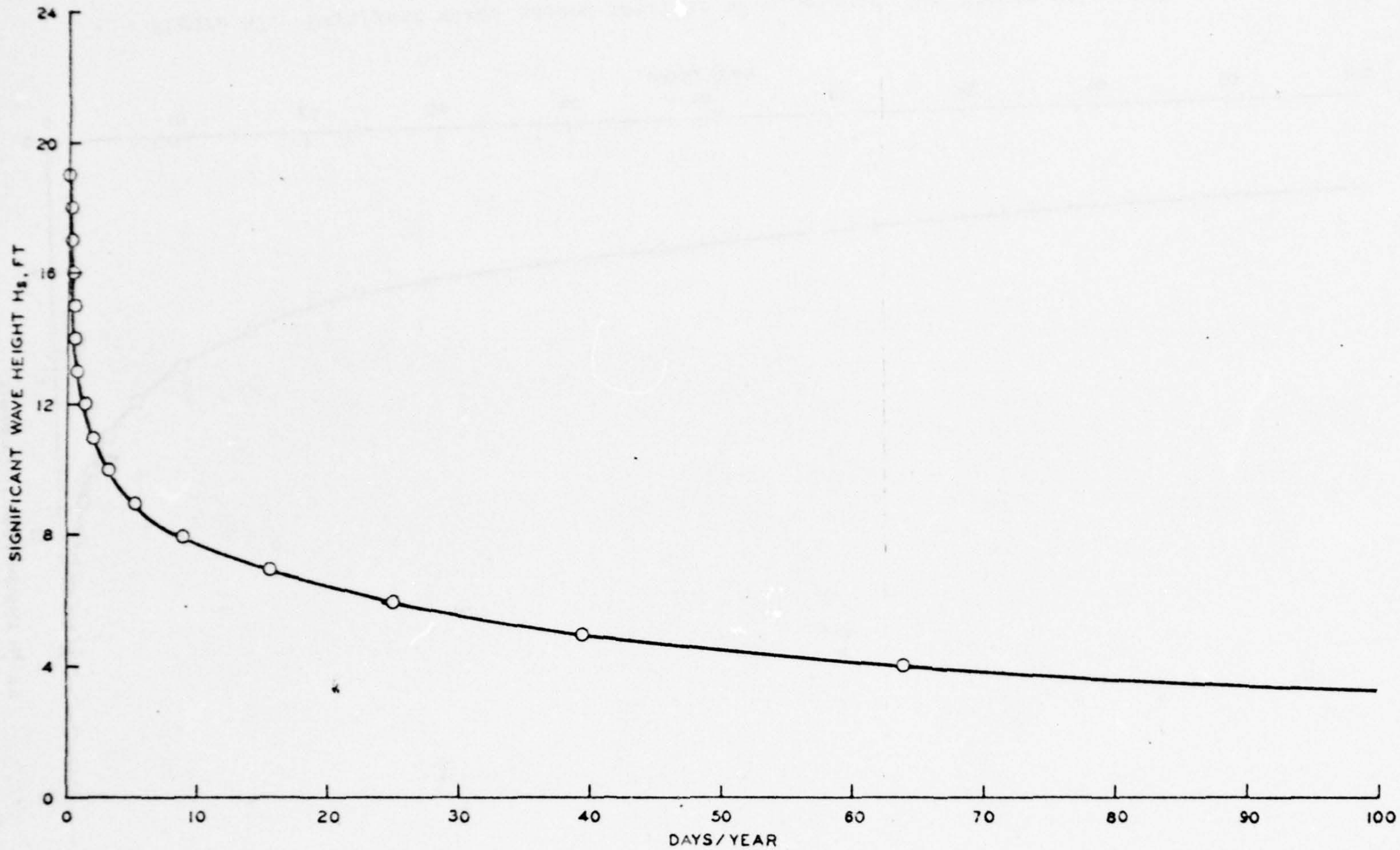


Figure 48. Days/year waves exceed specific wave heights, Point Estero LNG site

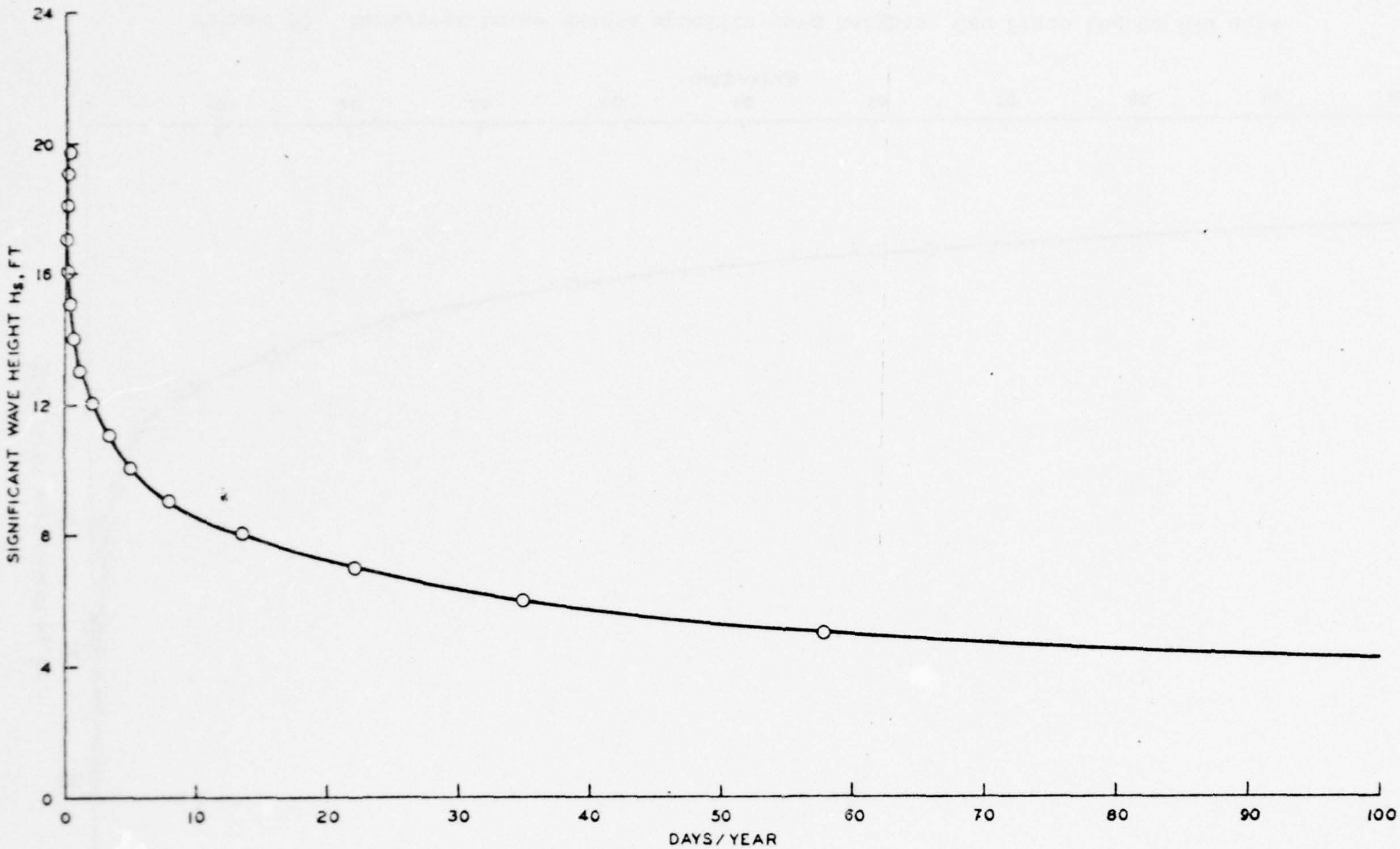


Figure 49. Days/year waves exceed specific wave heights, Point Buchon LNG site

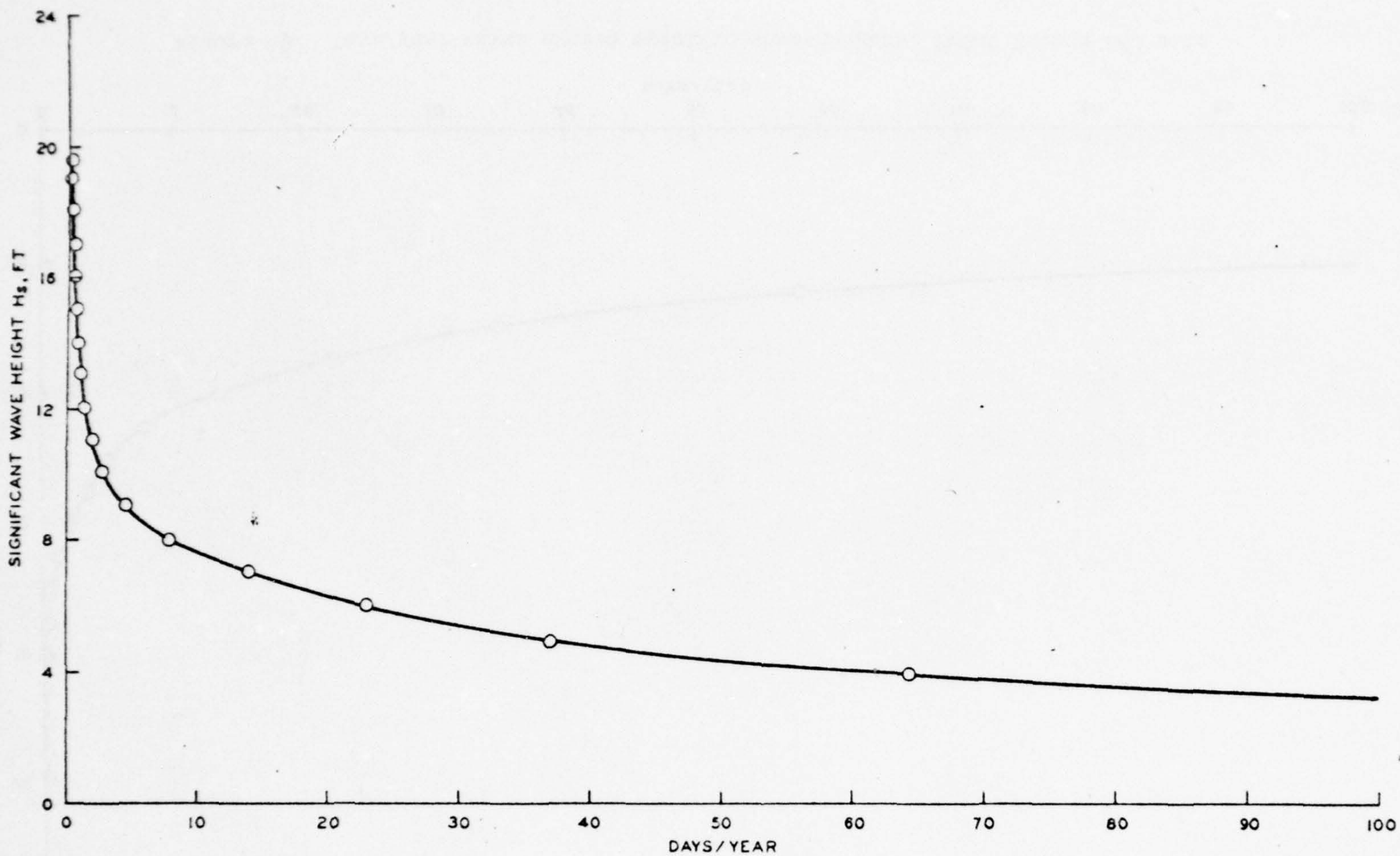


Figure 50. Days/year waves exceed specific wave heights, Oso Flaco Lagoon LNG site

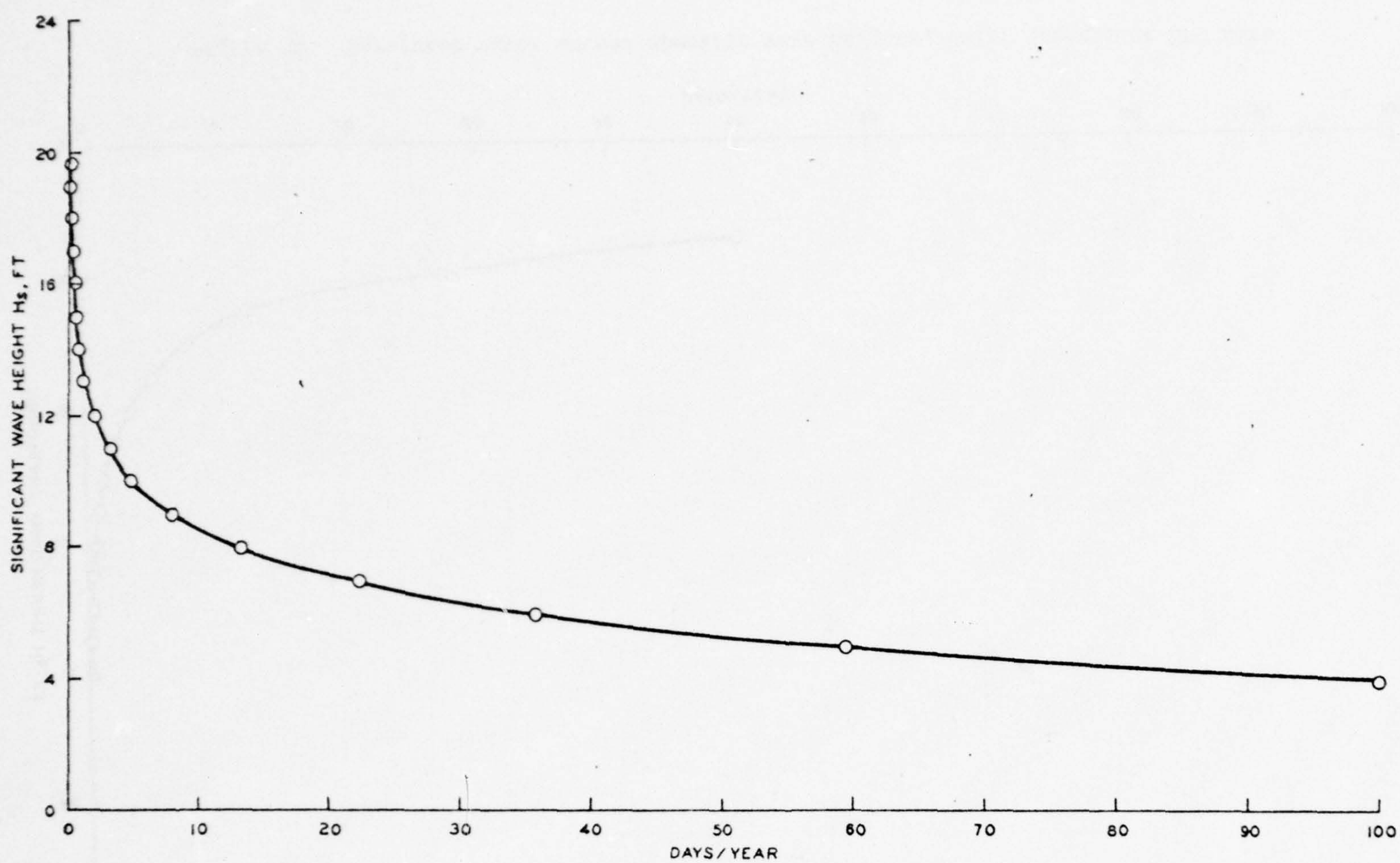


Figure 51. Days/year waves exceed specific wave heights, Guadalupe Dunes LNG site

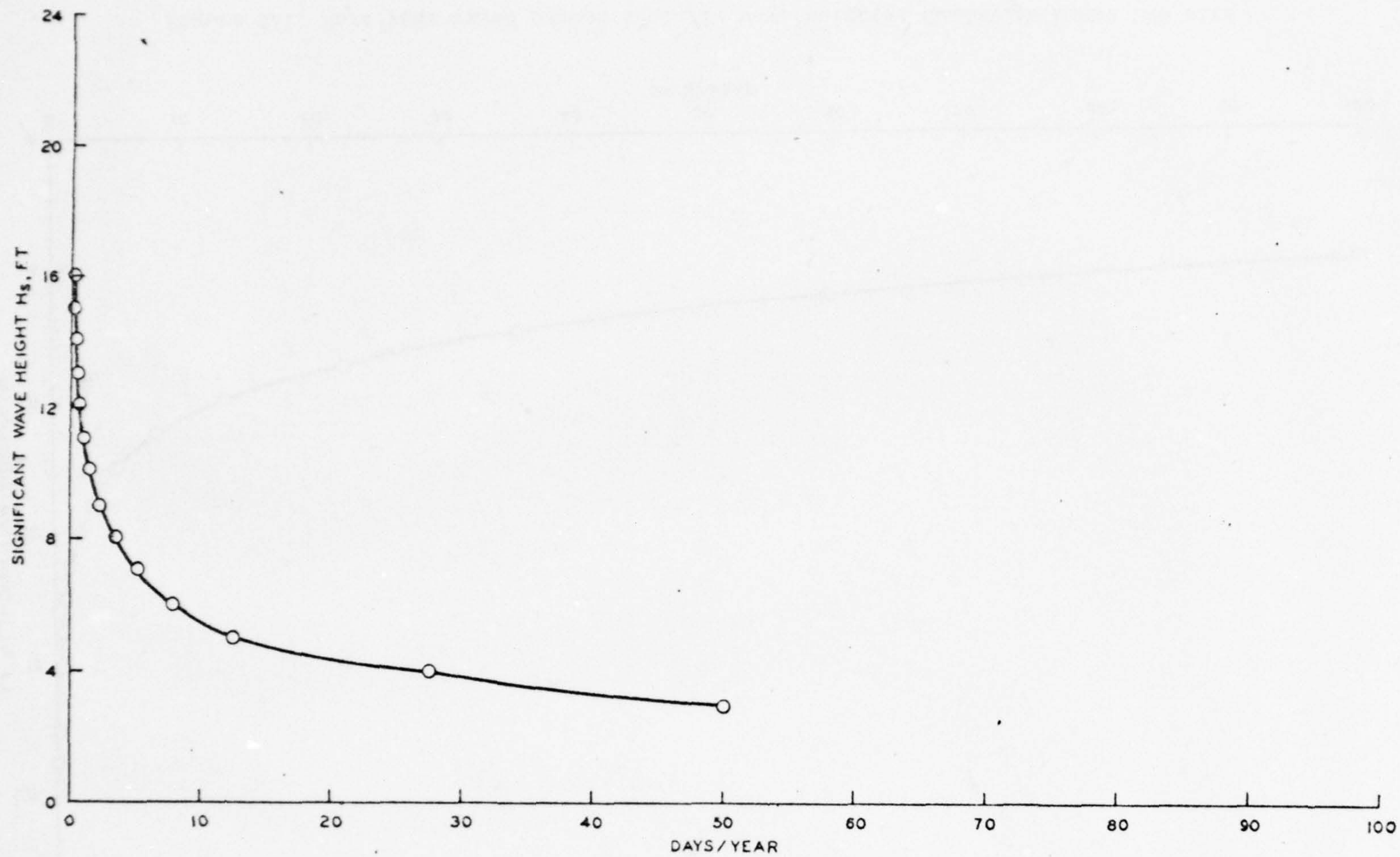


Figure 52. Days/year waves exceed specific wave heights, Point Conception LNG site

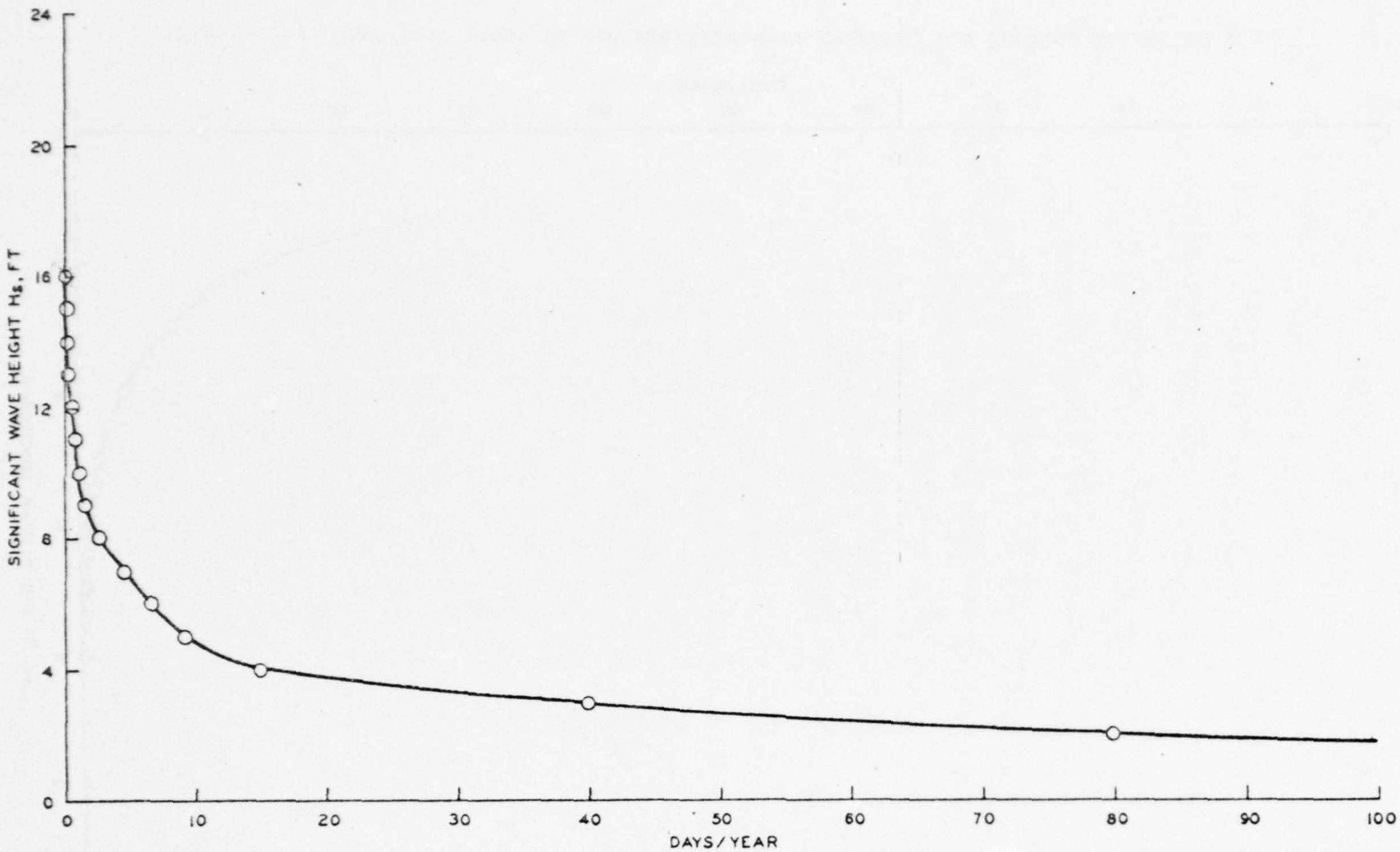


Figure 53. Days/year waves exceed specific wave heights, Tajiguas LNG site

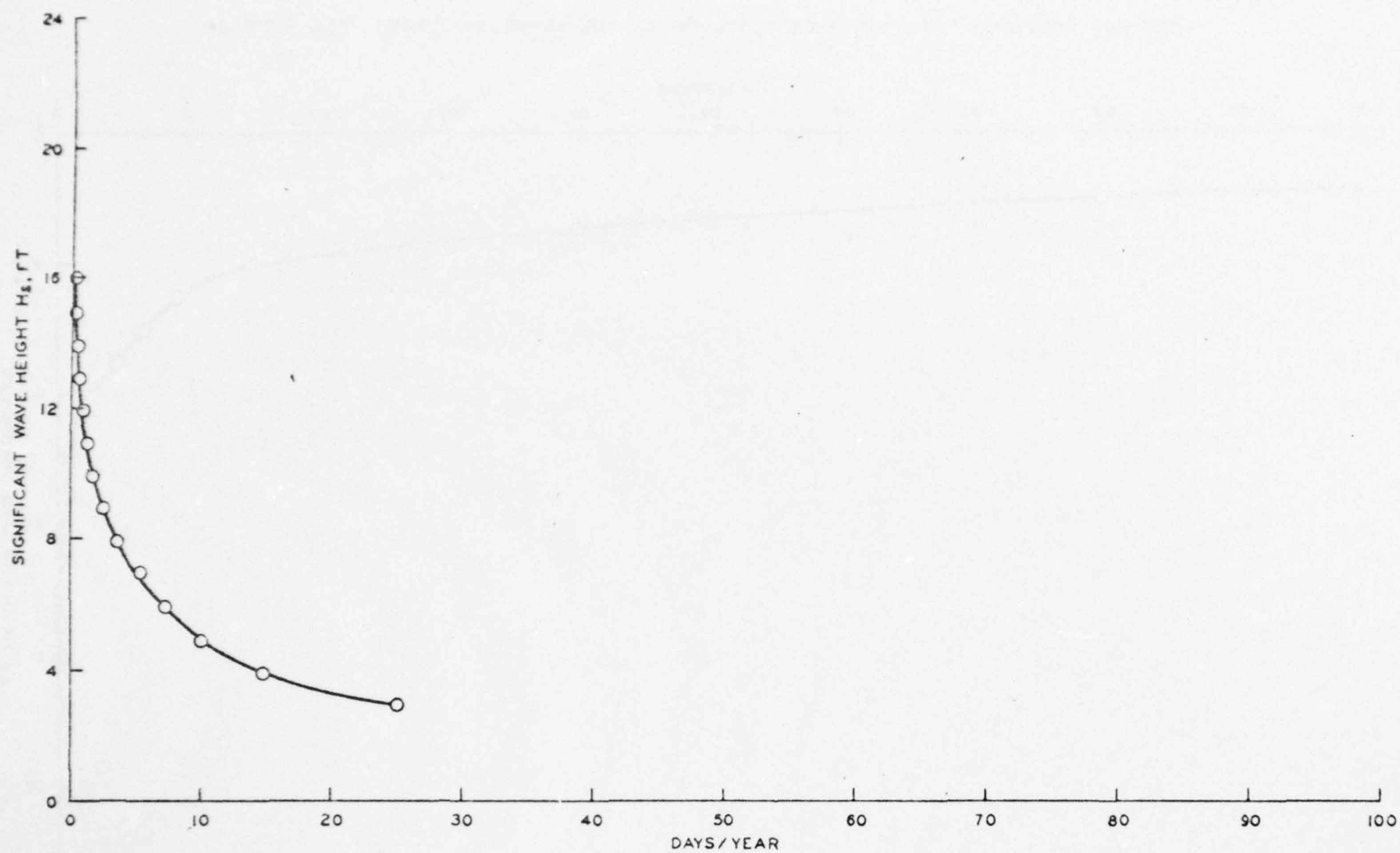


Figure 54. Days/year waves exceed specific wave heights, Dos Pueblos Ranch LNG site

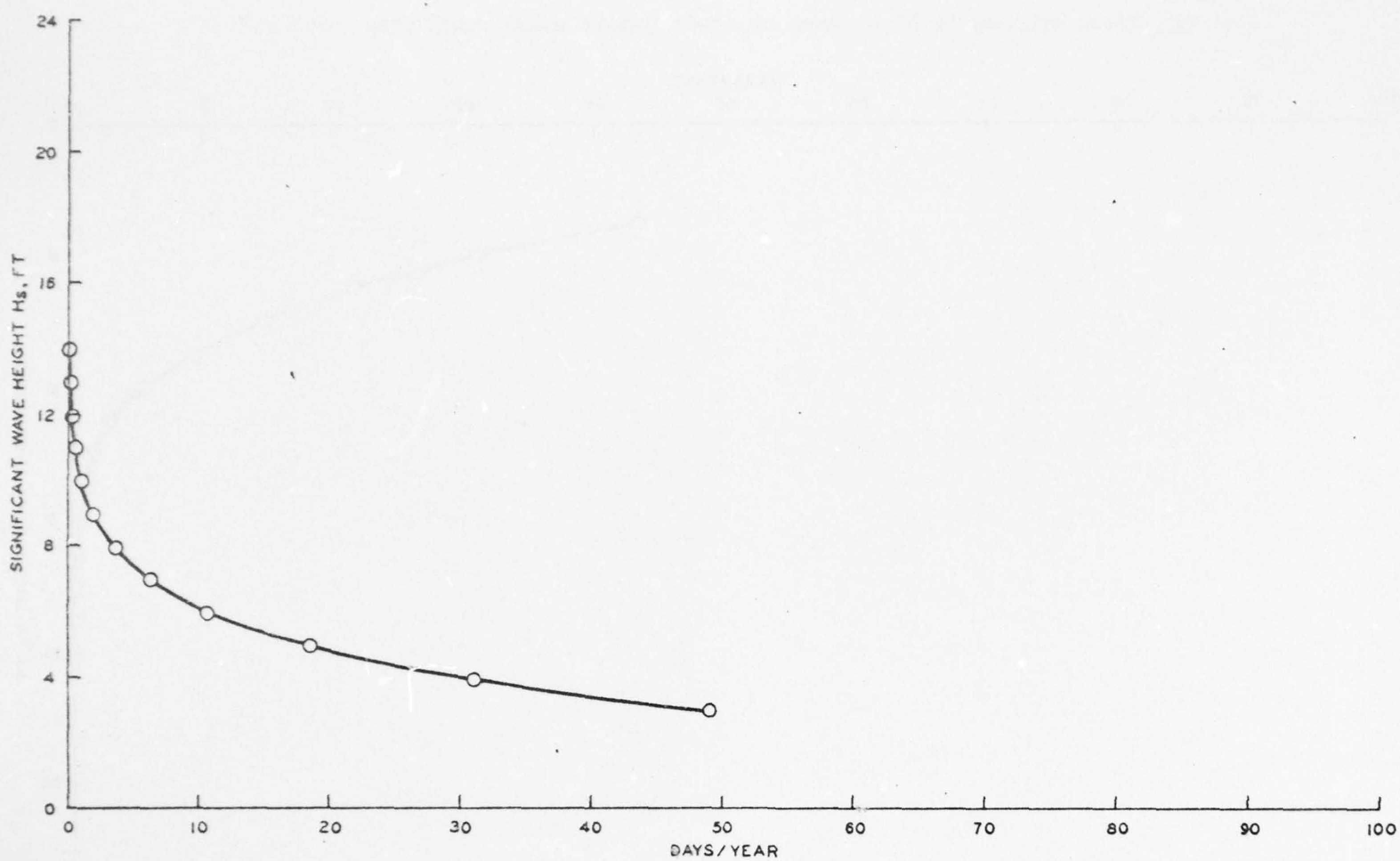


Figure 55. Days/year waves exceed specific wave heights, Deer Canyon LNG site

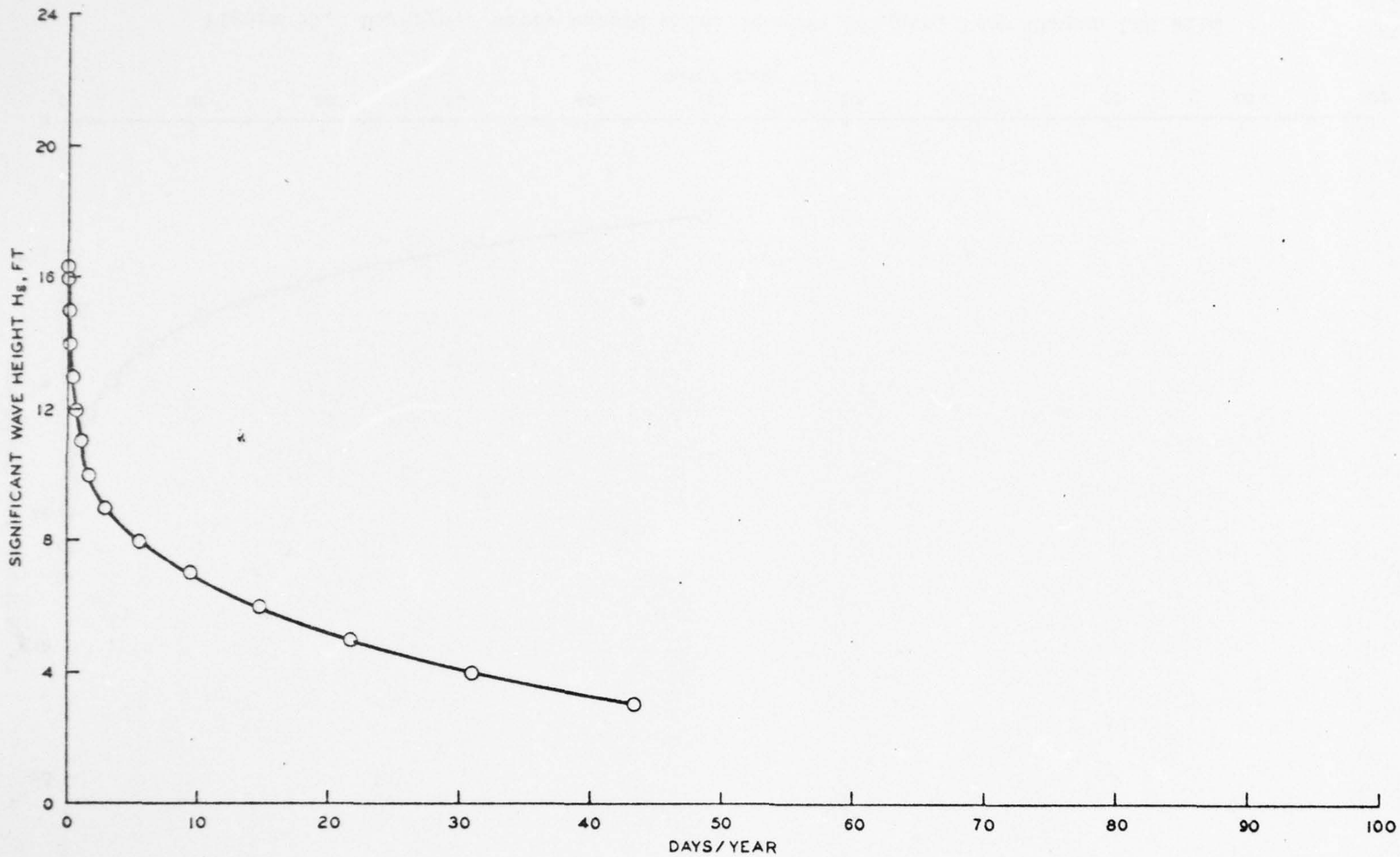


Figure 56. Days/year waves exceed specific wave heights, Redondo Beach LNG site

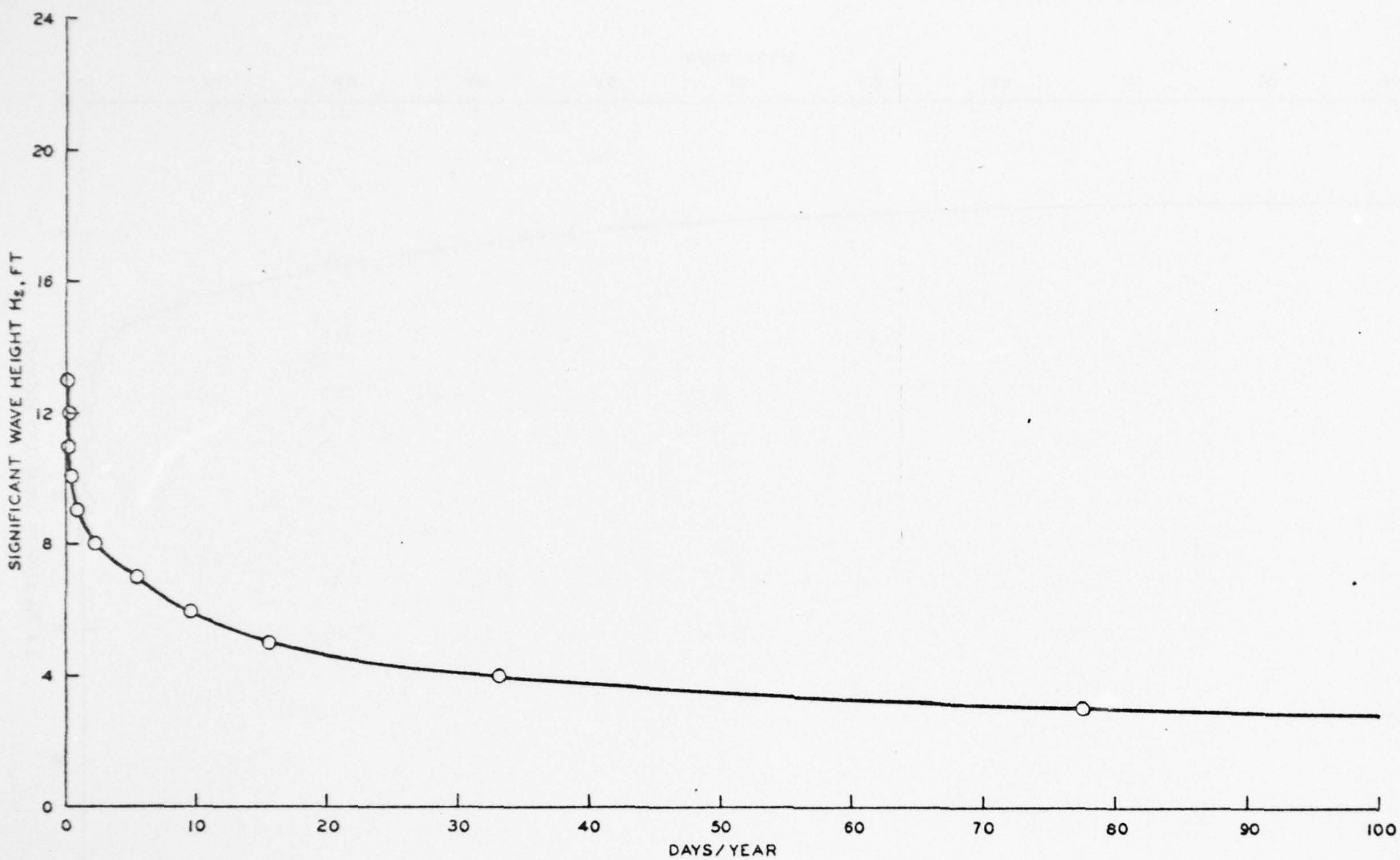


Figure 57. Days/year waves exceed specific wave heights, Camp Pendelton LNG site

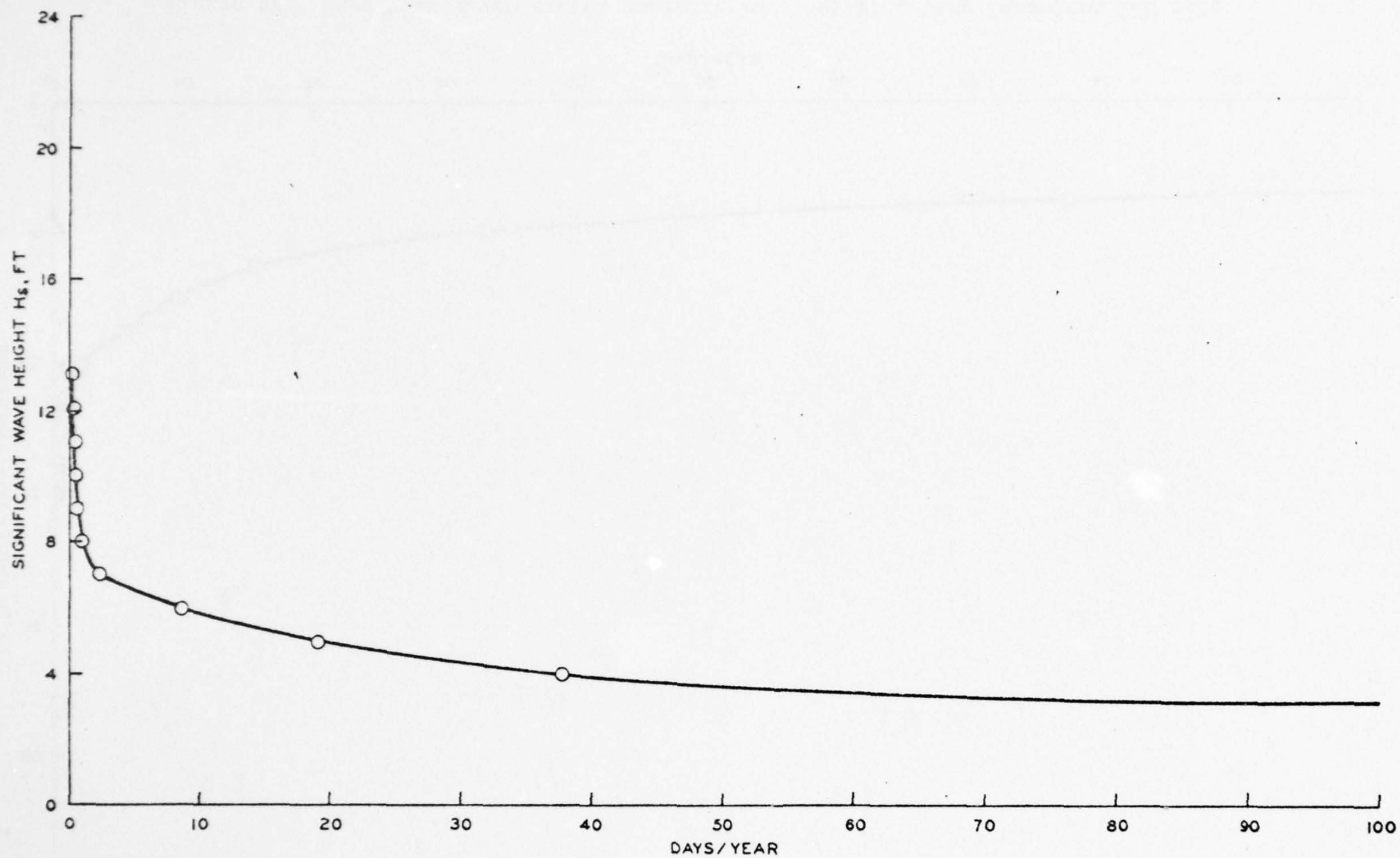


Figure 58. Days/year waves exceed specific wave heights, Oceanside LNG site

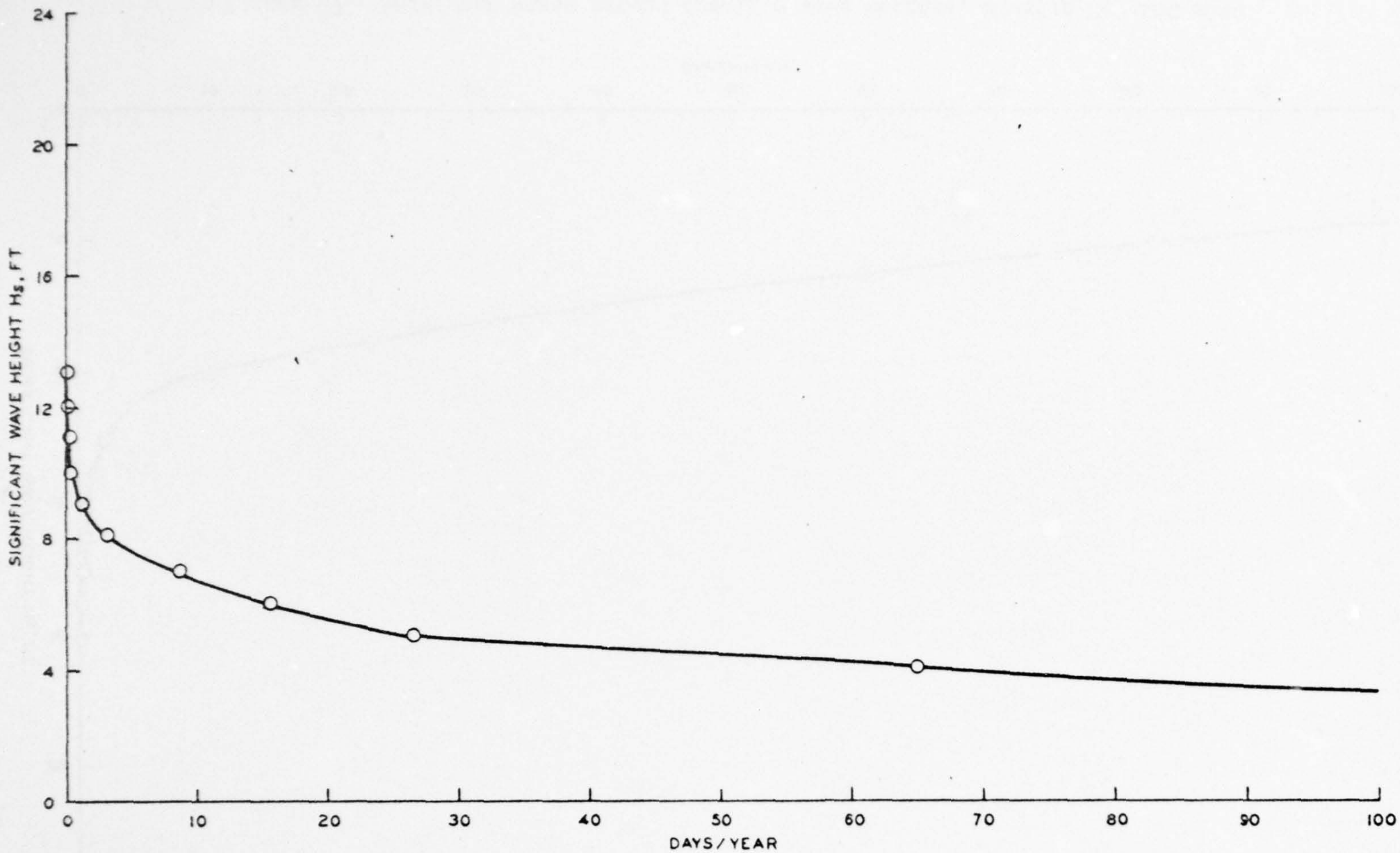


Figure 59. Days/year waves exceed specific wave heights, Encinitas LNG site

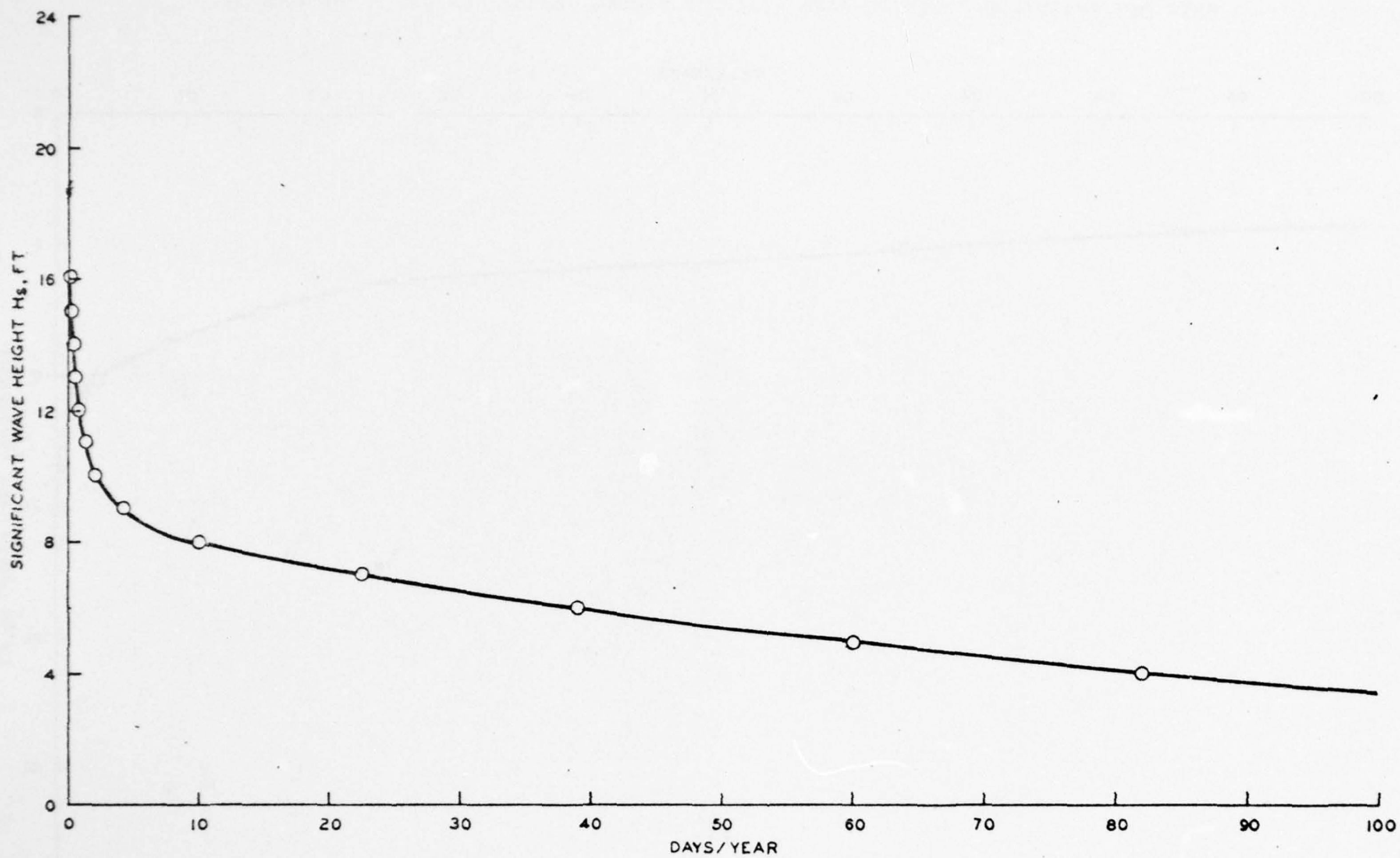


Figure 60. Days/year waves exceed specific wave heights, Mission Bay LNG site

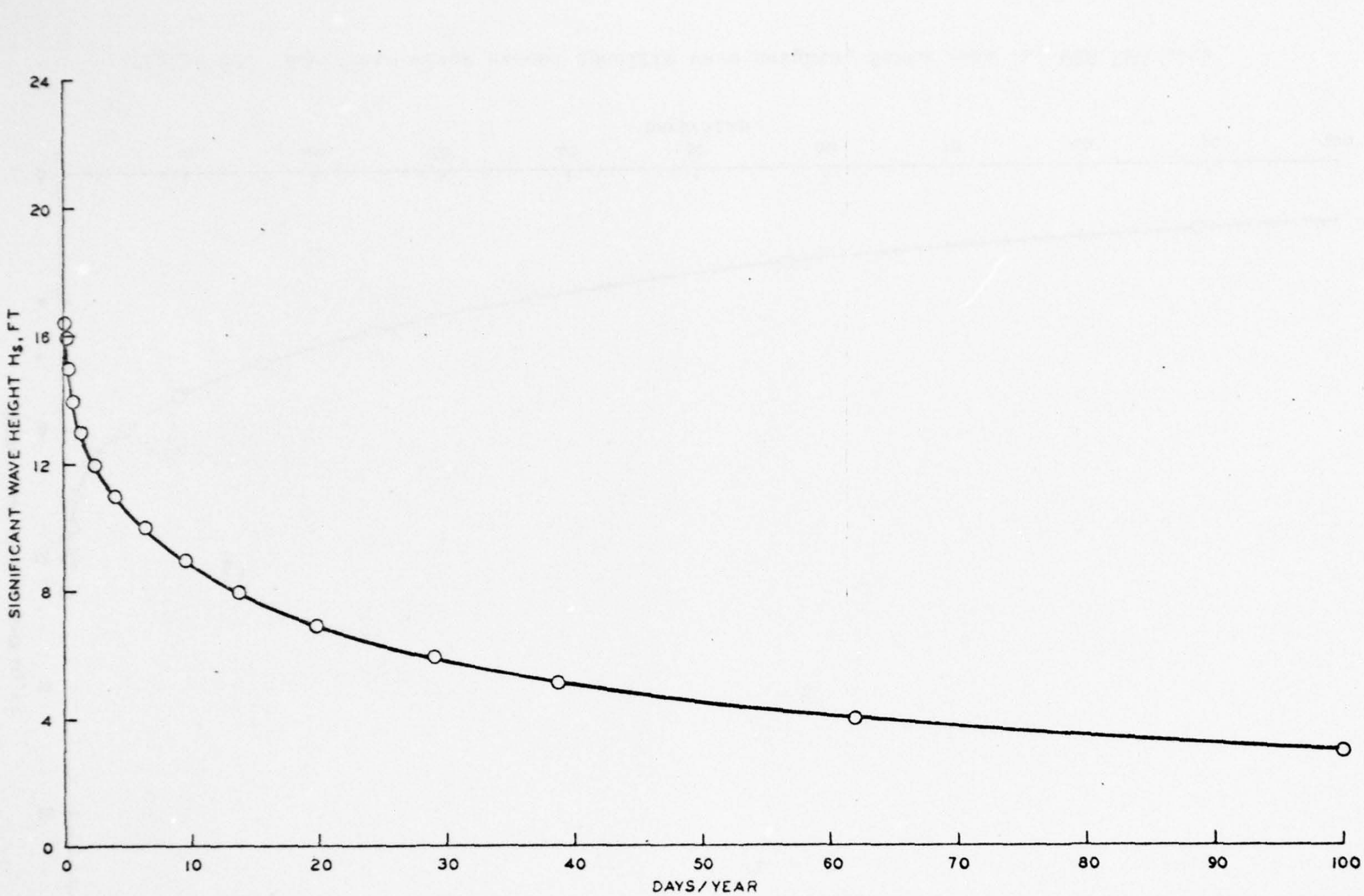


Figure 61. Days/year waves exceed specific wave heights, Santa Rosa Is. CCC LNG site

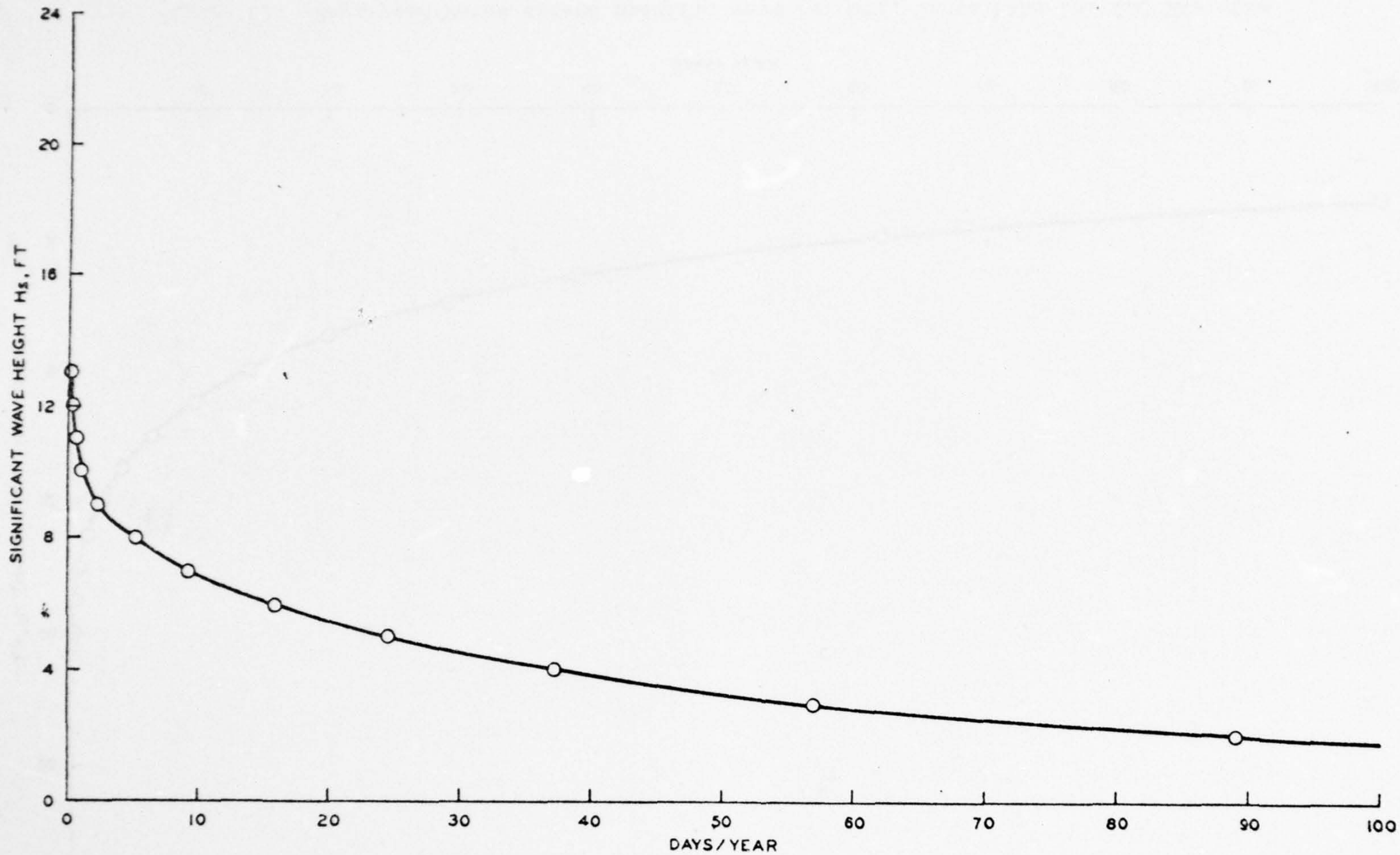


Figure 62. Days/year waves exceed specific wave heights, Santa Rosa Is. WES LNG site

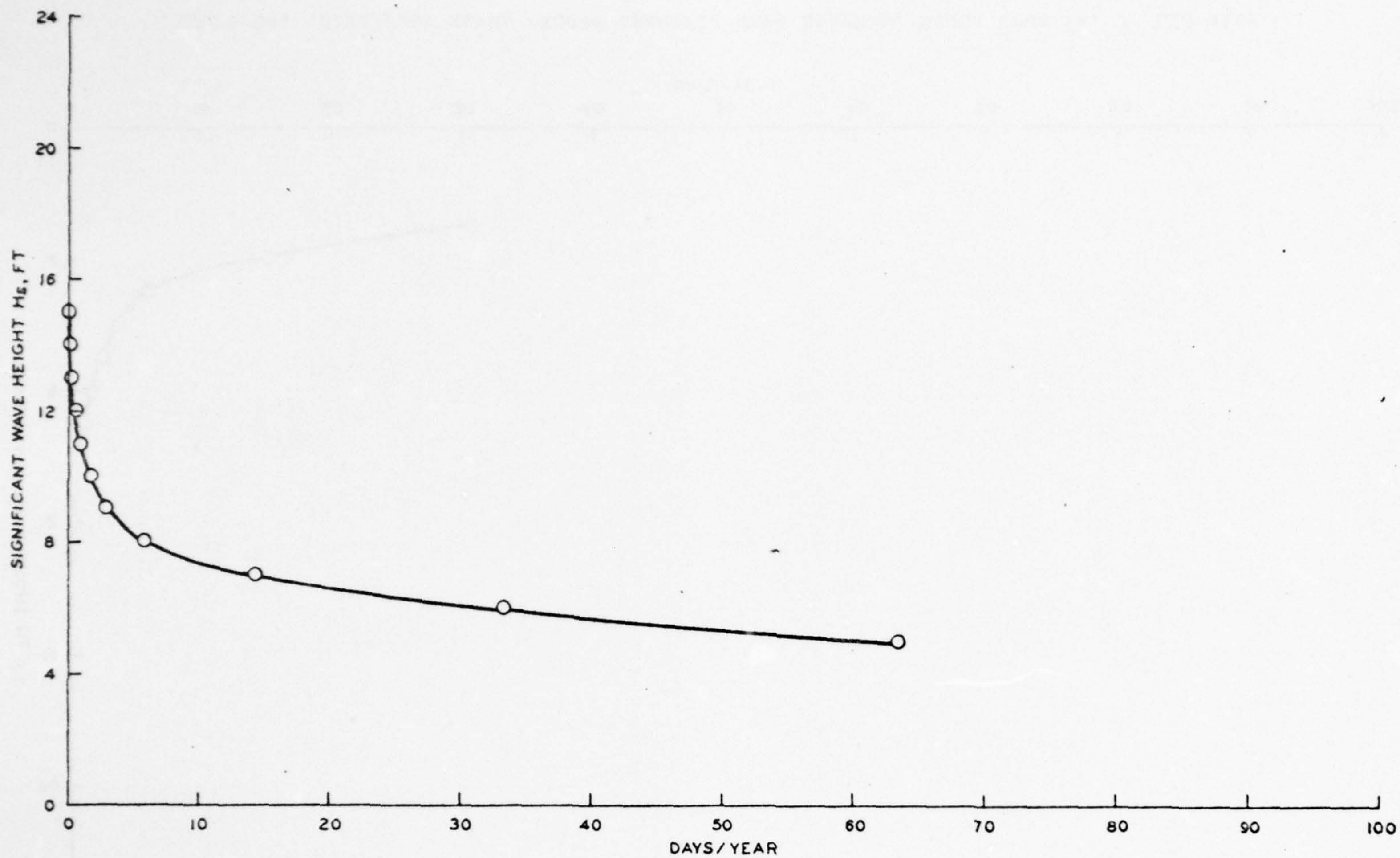


Figure 63. Days/year waves exceed specific wave heights, Santa Cruz Is. N. LNG site

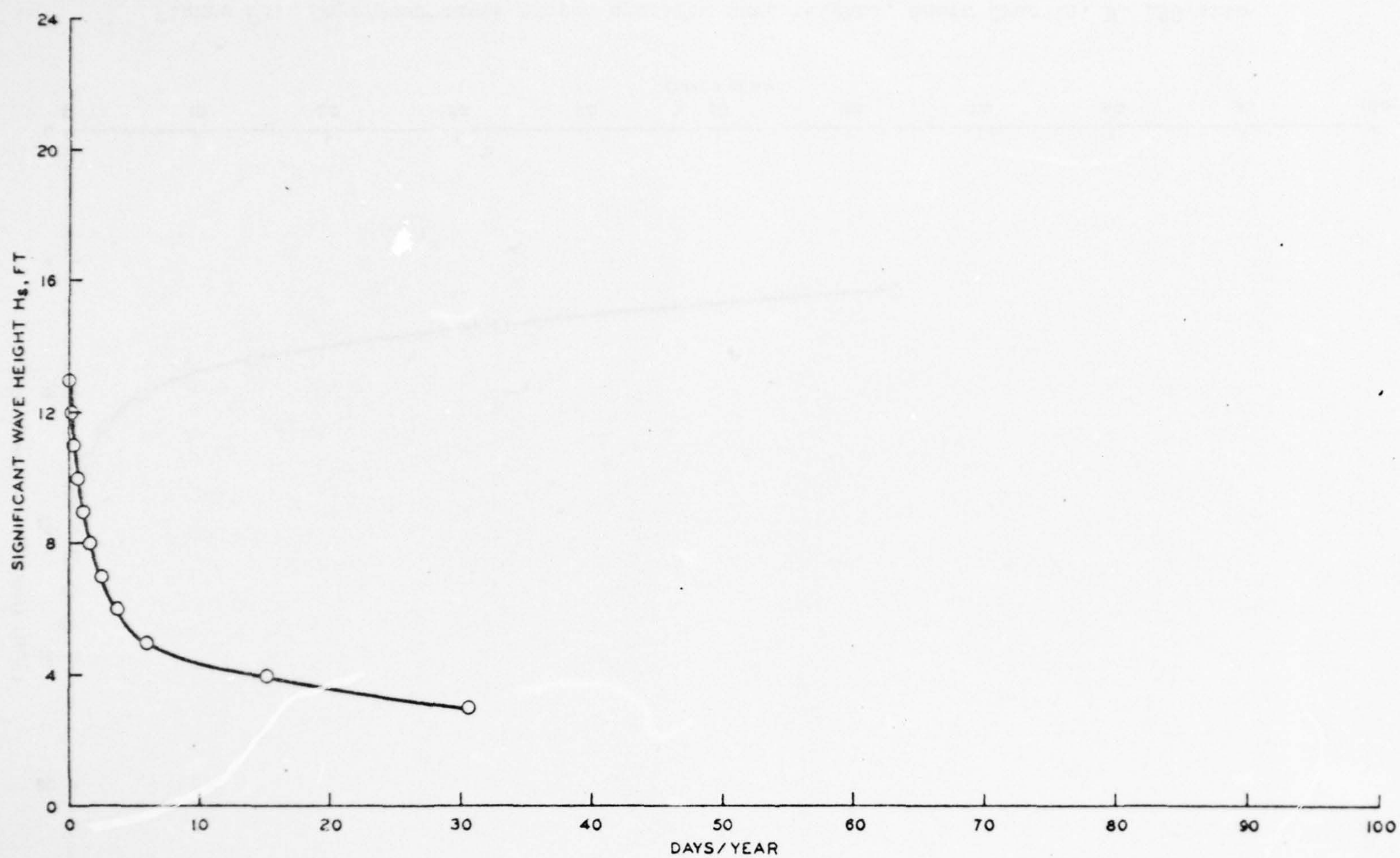


Figure 64. Days/year waves exceed specific wave heights, Santa Cruz Is. E. LNG site

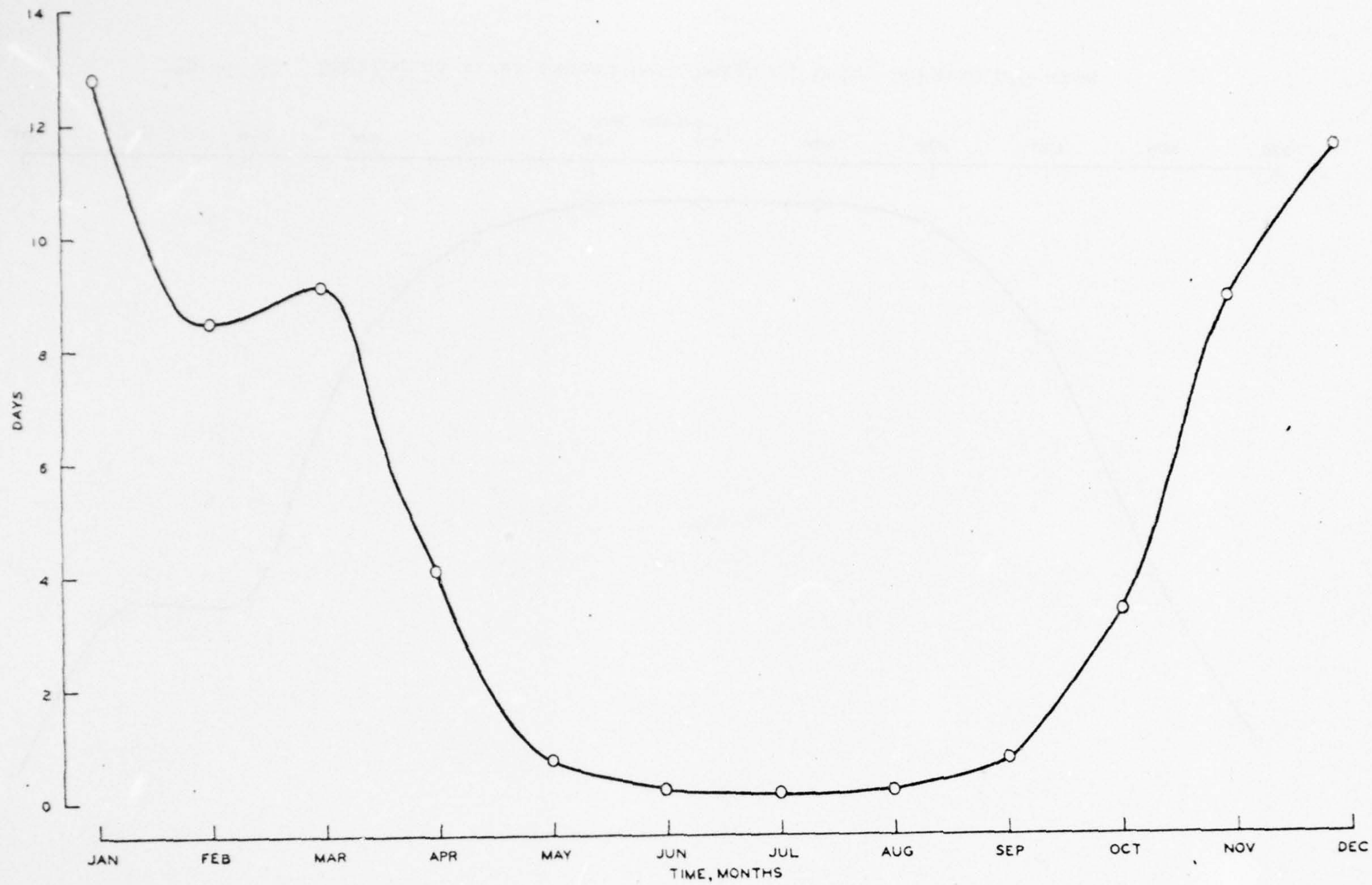


Figure 65. Days/month waves exceed 6-ft heights, Crescent City LNG site

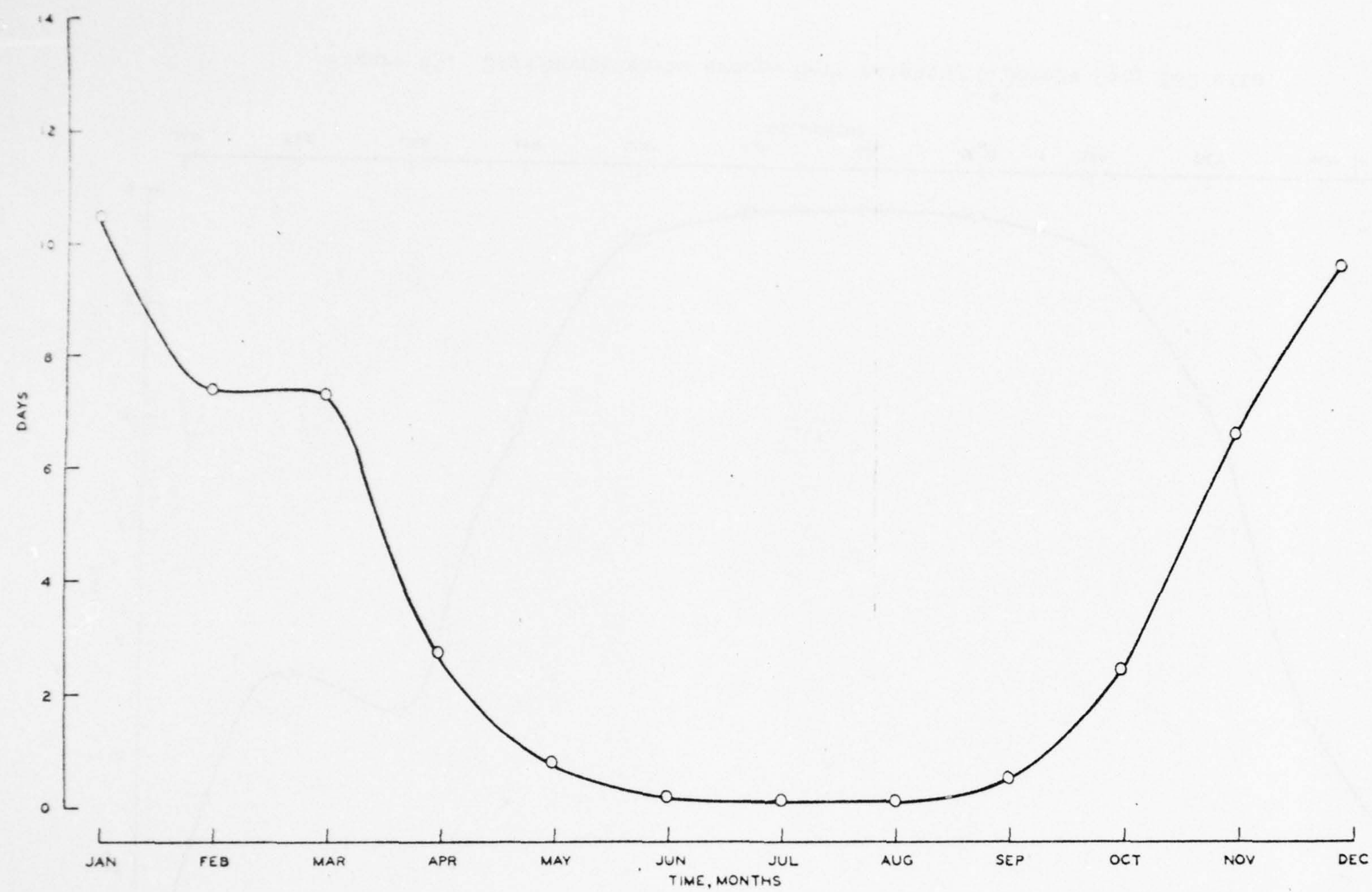


Figure 66. Days/month waves exceed 6-ft heights, Point Delgada LNG site

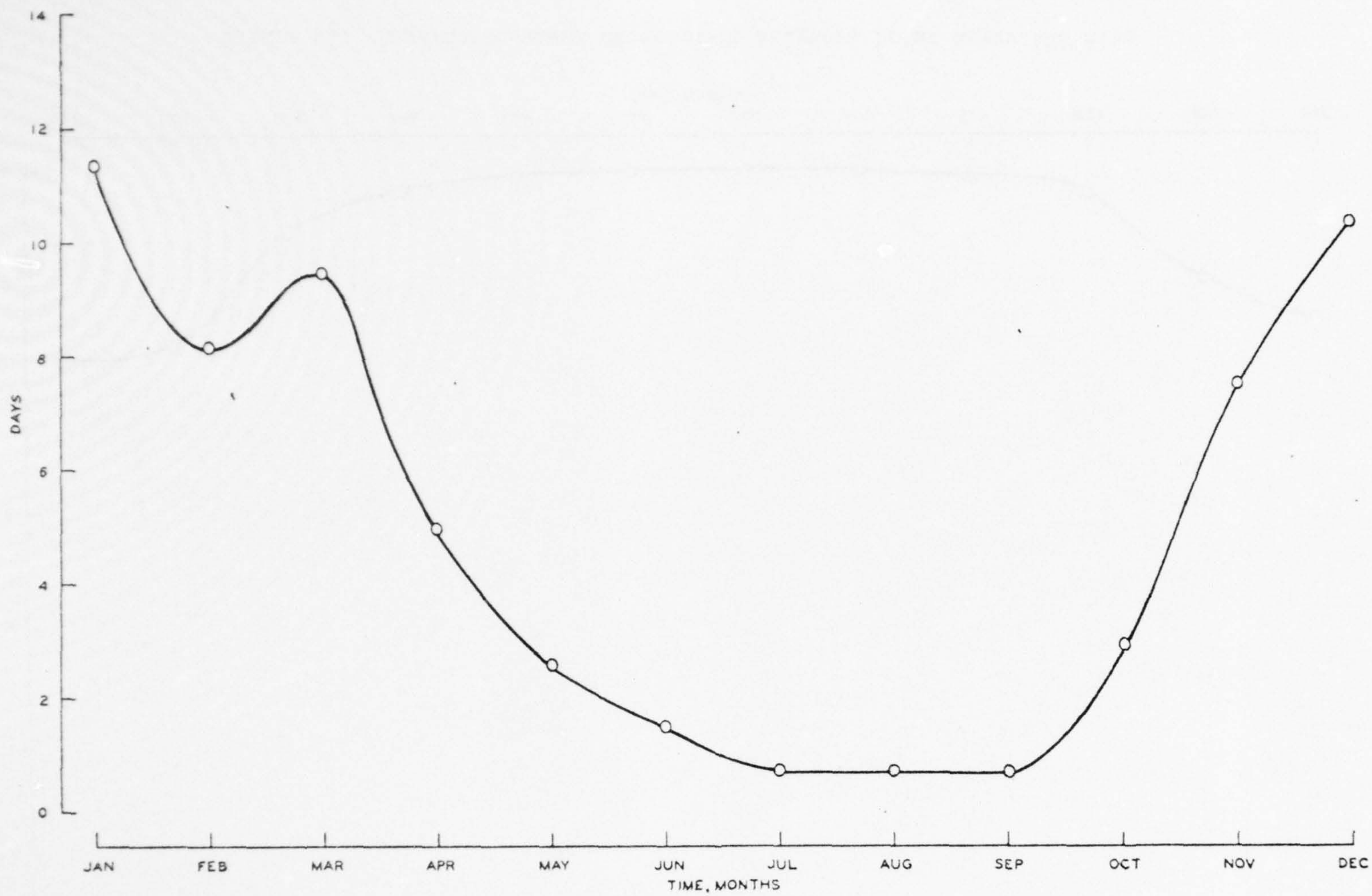


Figure 67. Days/month waves exceed 6-ft heights, Point Arena LNG site

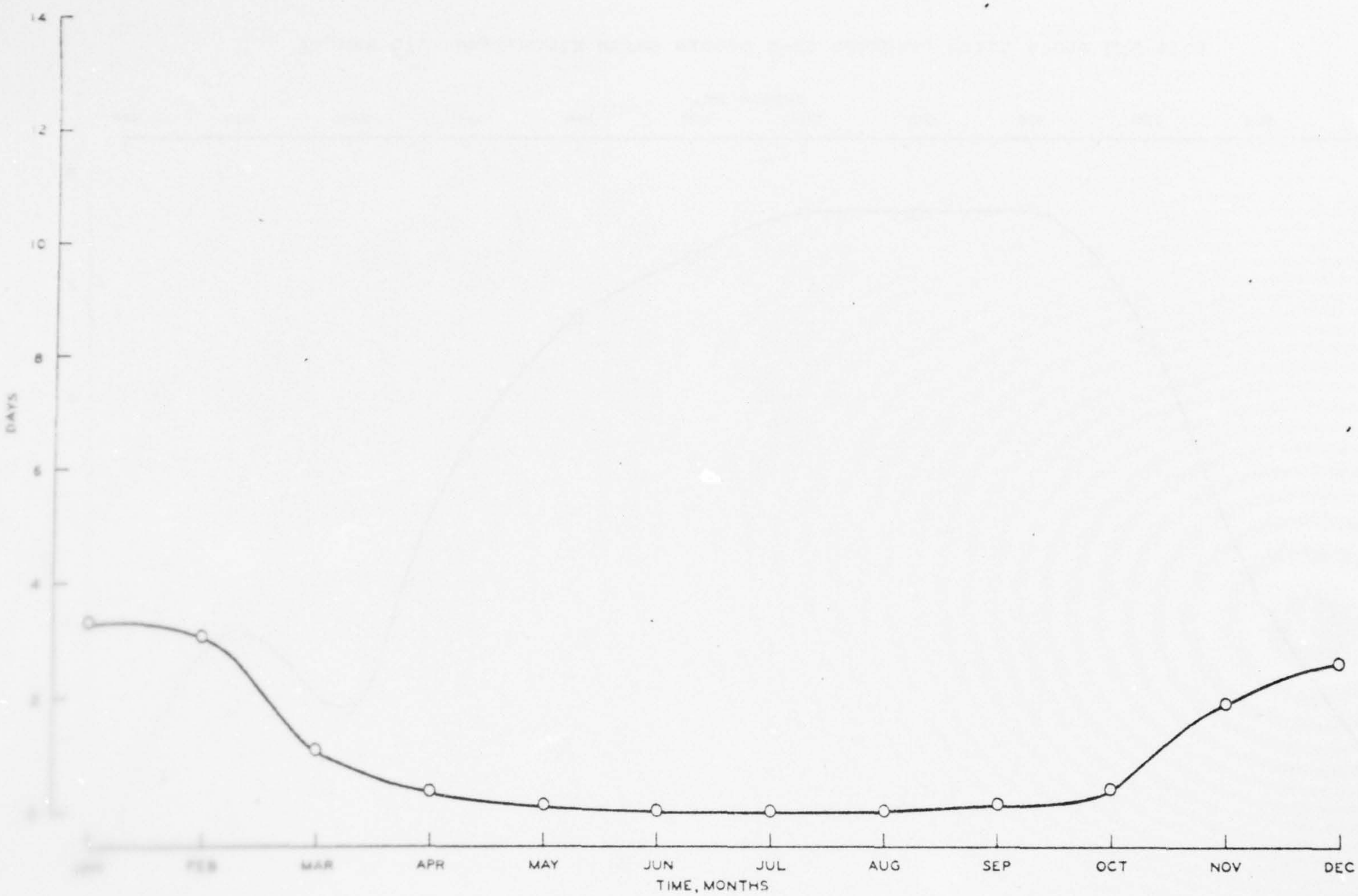


Figure 68. Days/month waves exceed 6-ft heights, Point Reyes LNG site

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PRELIMINARY EVALUATION OF WIND AND WAVE EFFECTS AT POTENTIAL LN--ETC(U)
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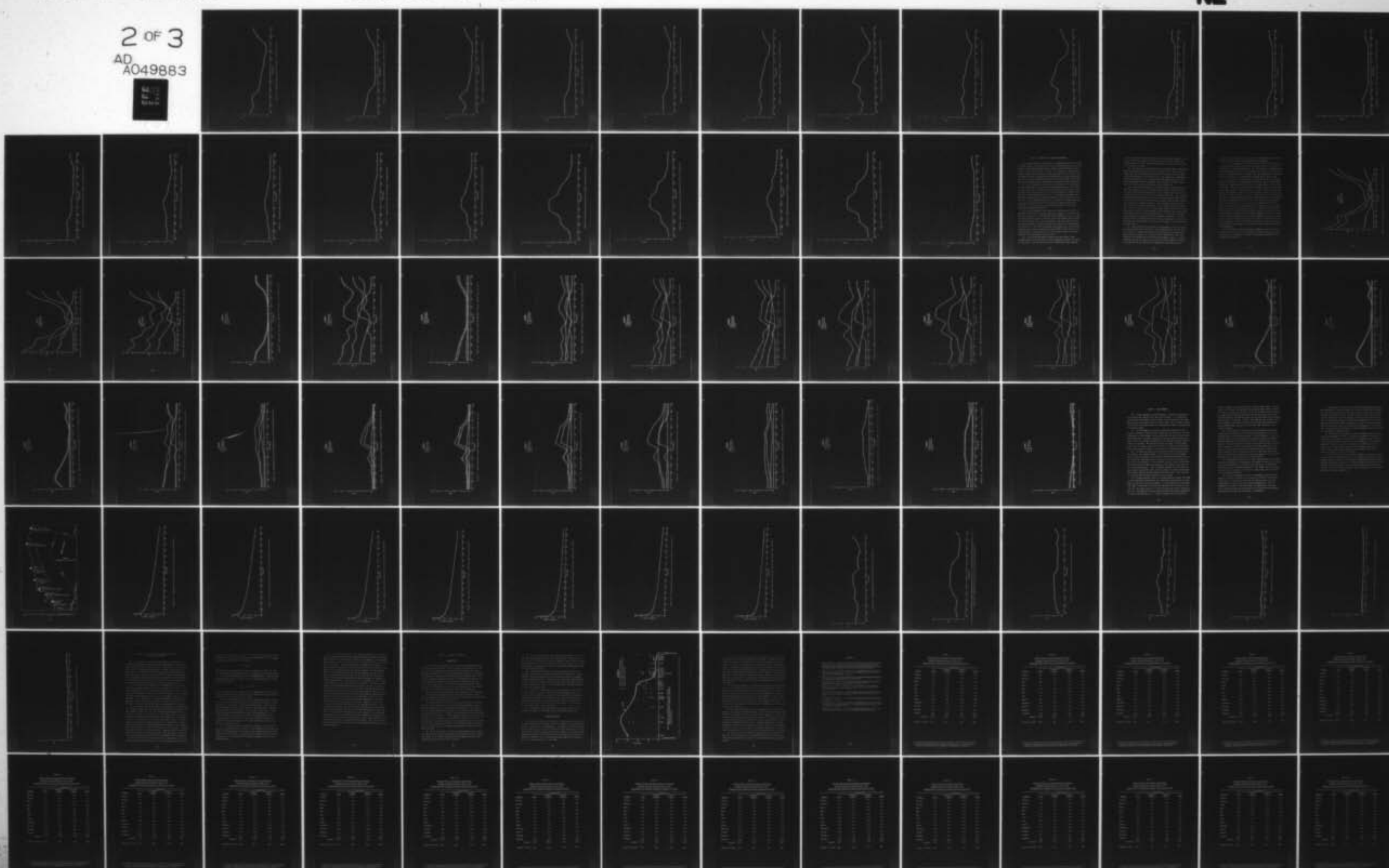

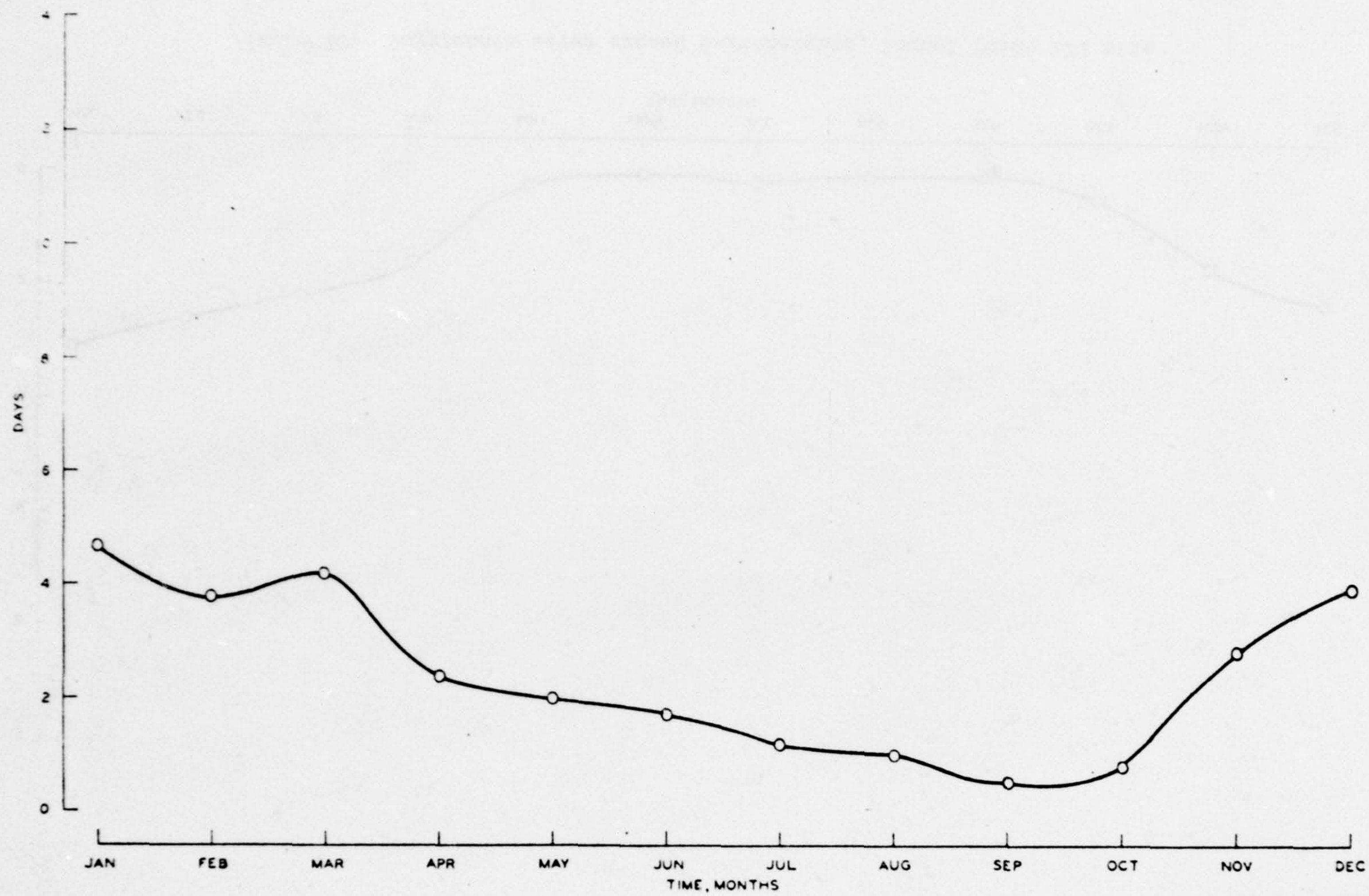

Figure 69. Days/month waves exceed 6-ft heights, Davenport LNG site

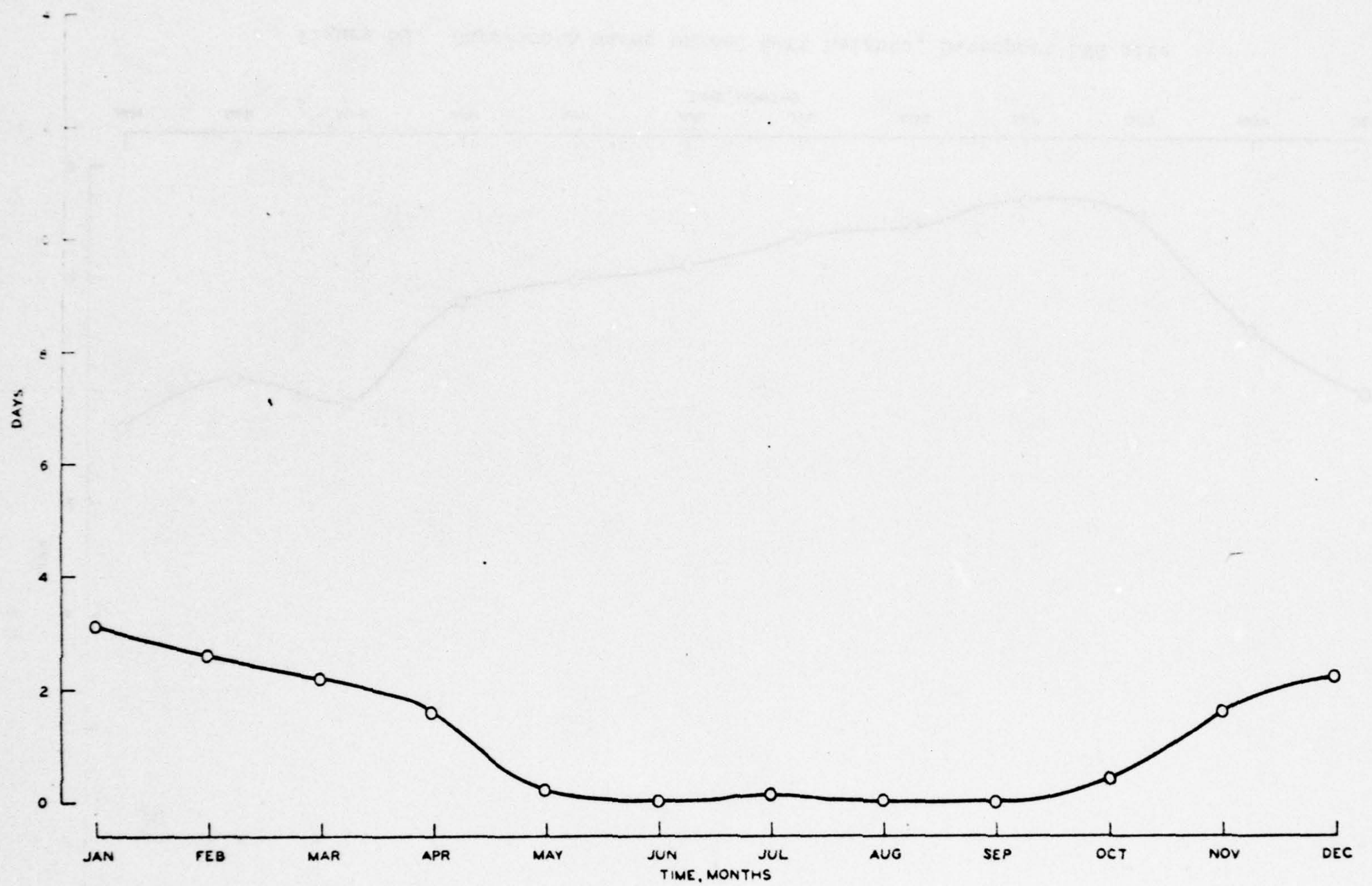

Figure 70. Days/month waves exceed 6-ft heights, Soquel Point LNG site

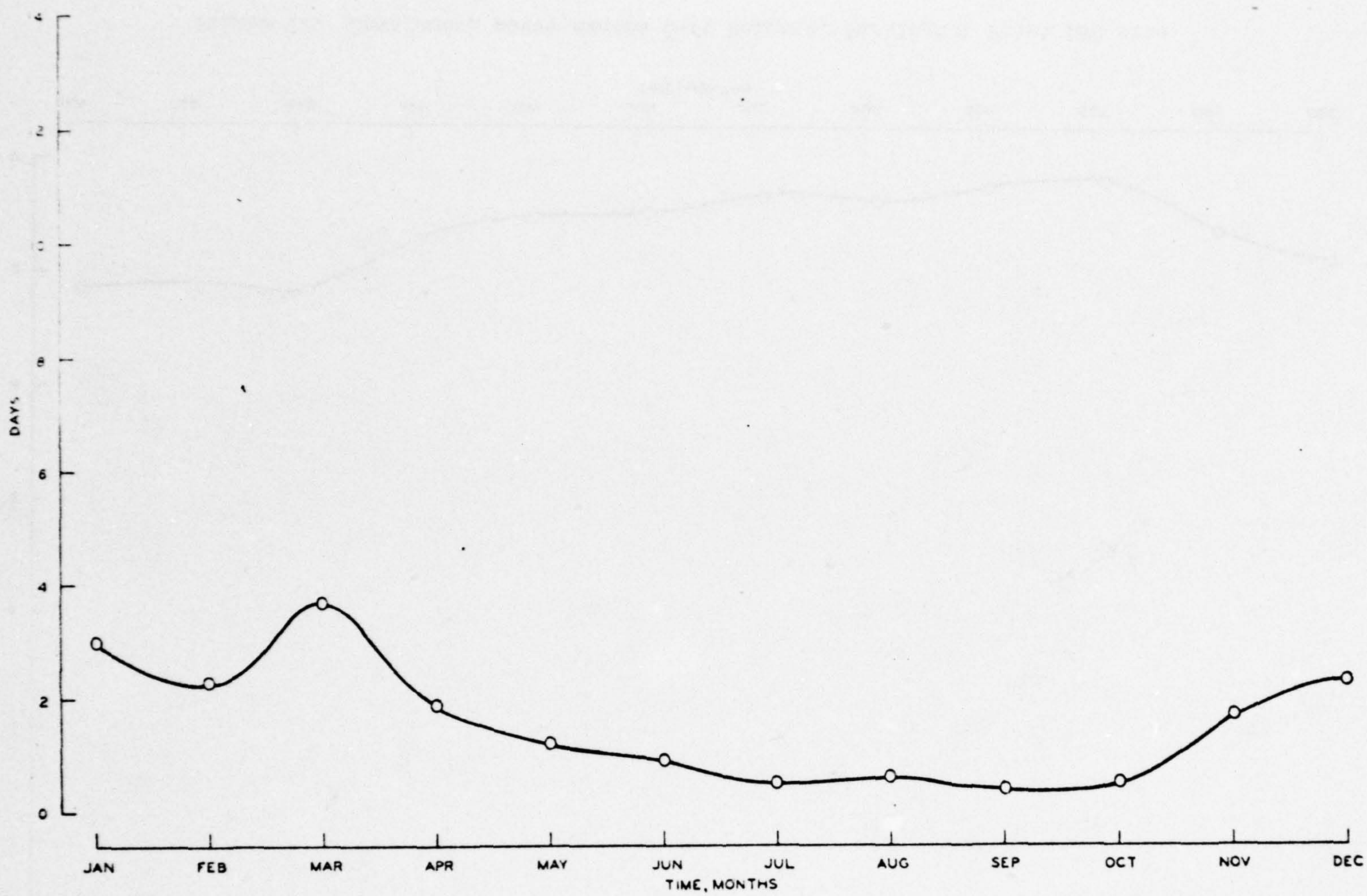

Figure 71. Days/month waves exceed 6-ft heights, Moss Landing LNG site

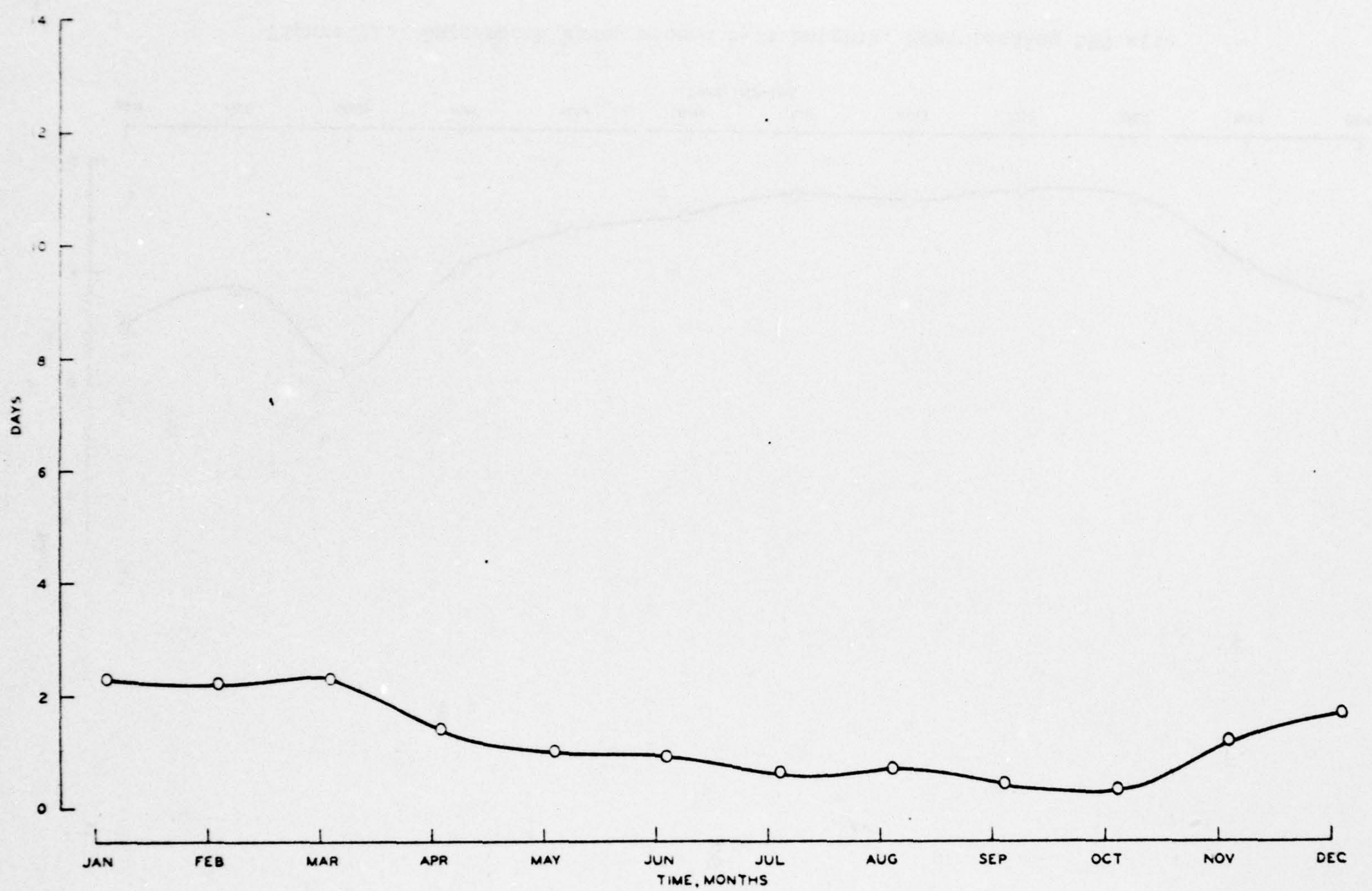

Figure 72. Days/month waves exceed 6-ft heights, Partington Point LNG site

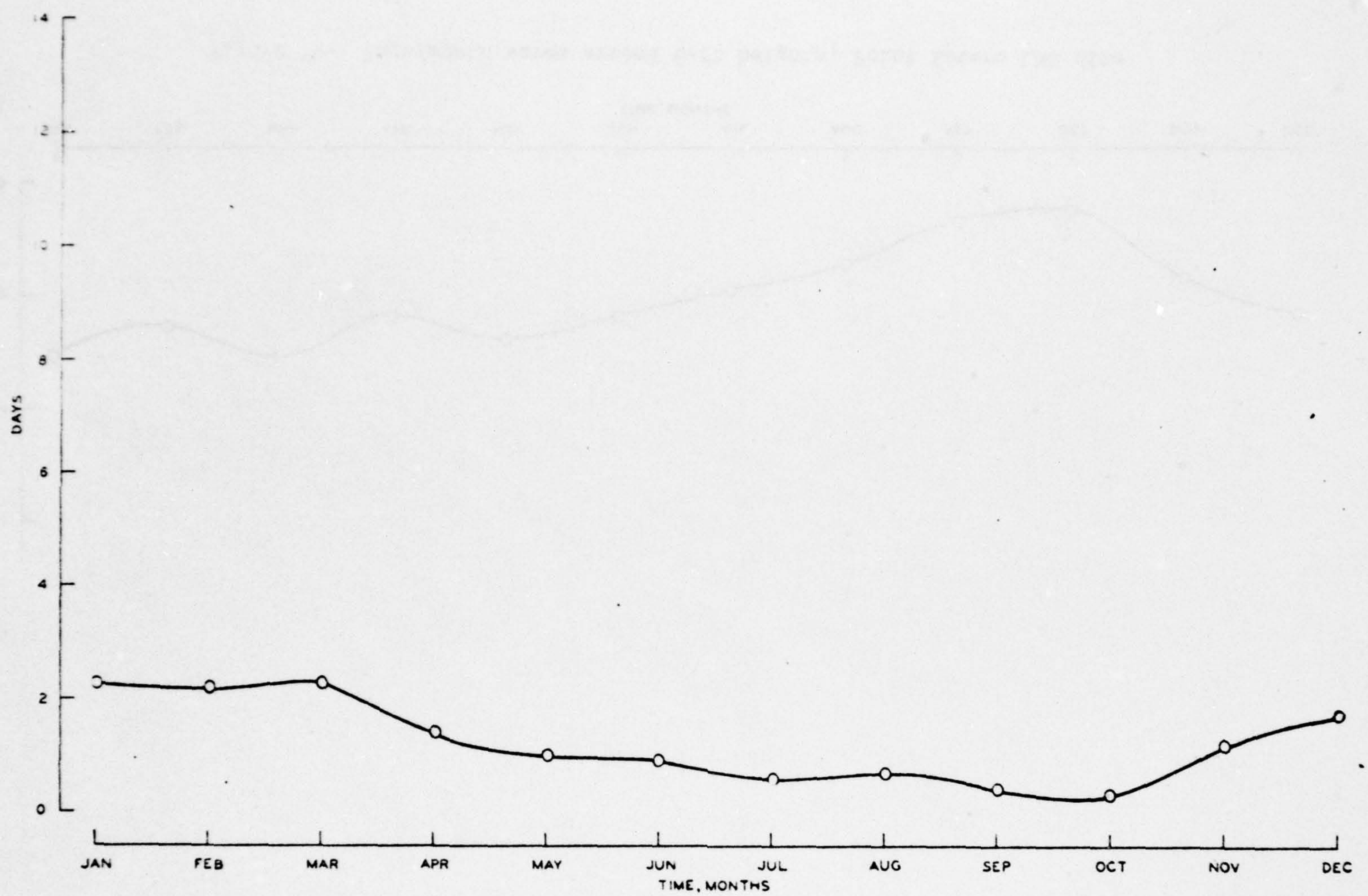

Figure 73. Days/month waves exceed 6-ft heights, San Simeon Point LNG site

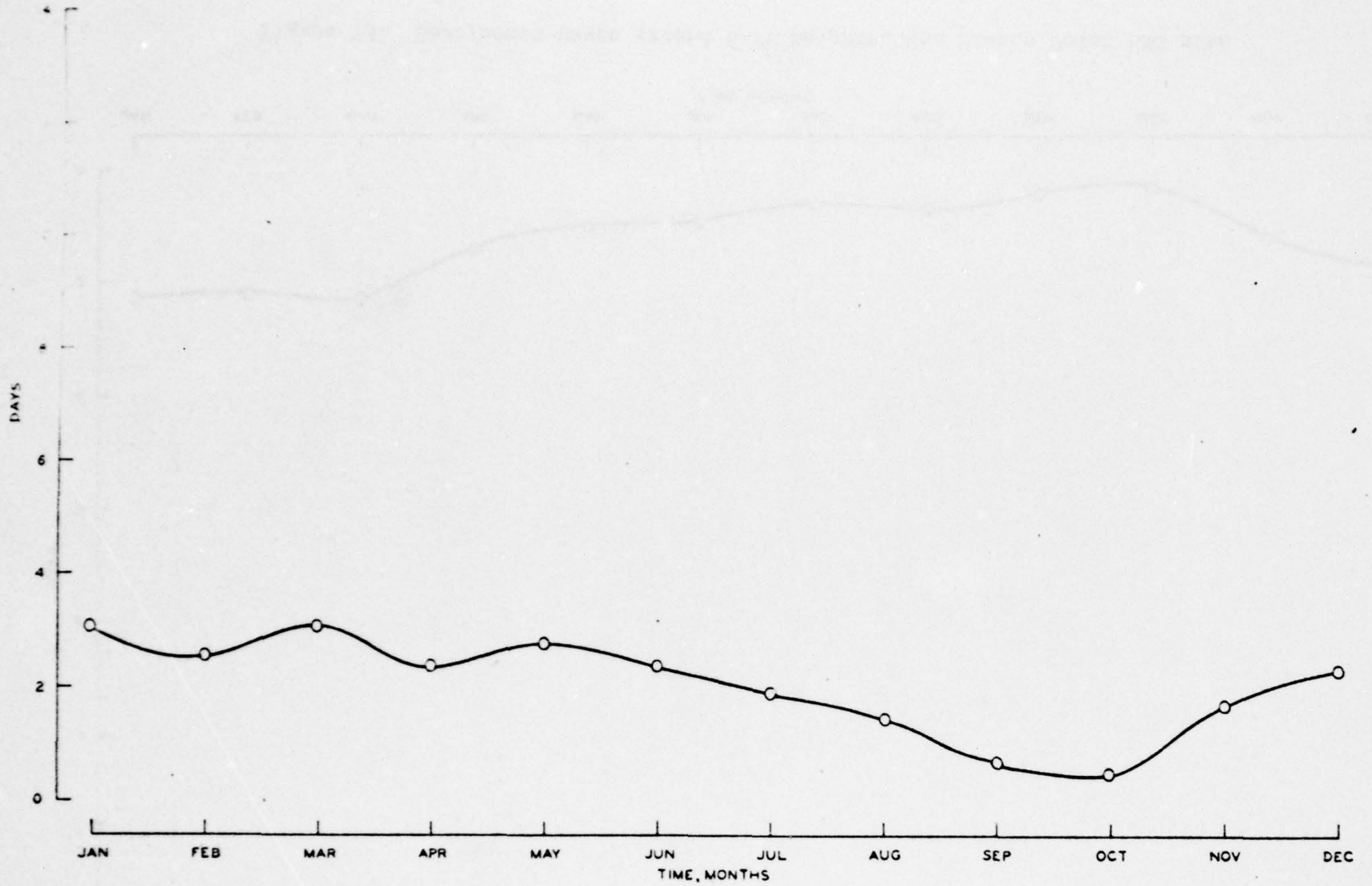

Figure 74. Days/month waves exceed 6-ft heights, Point Estero LNG site

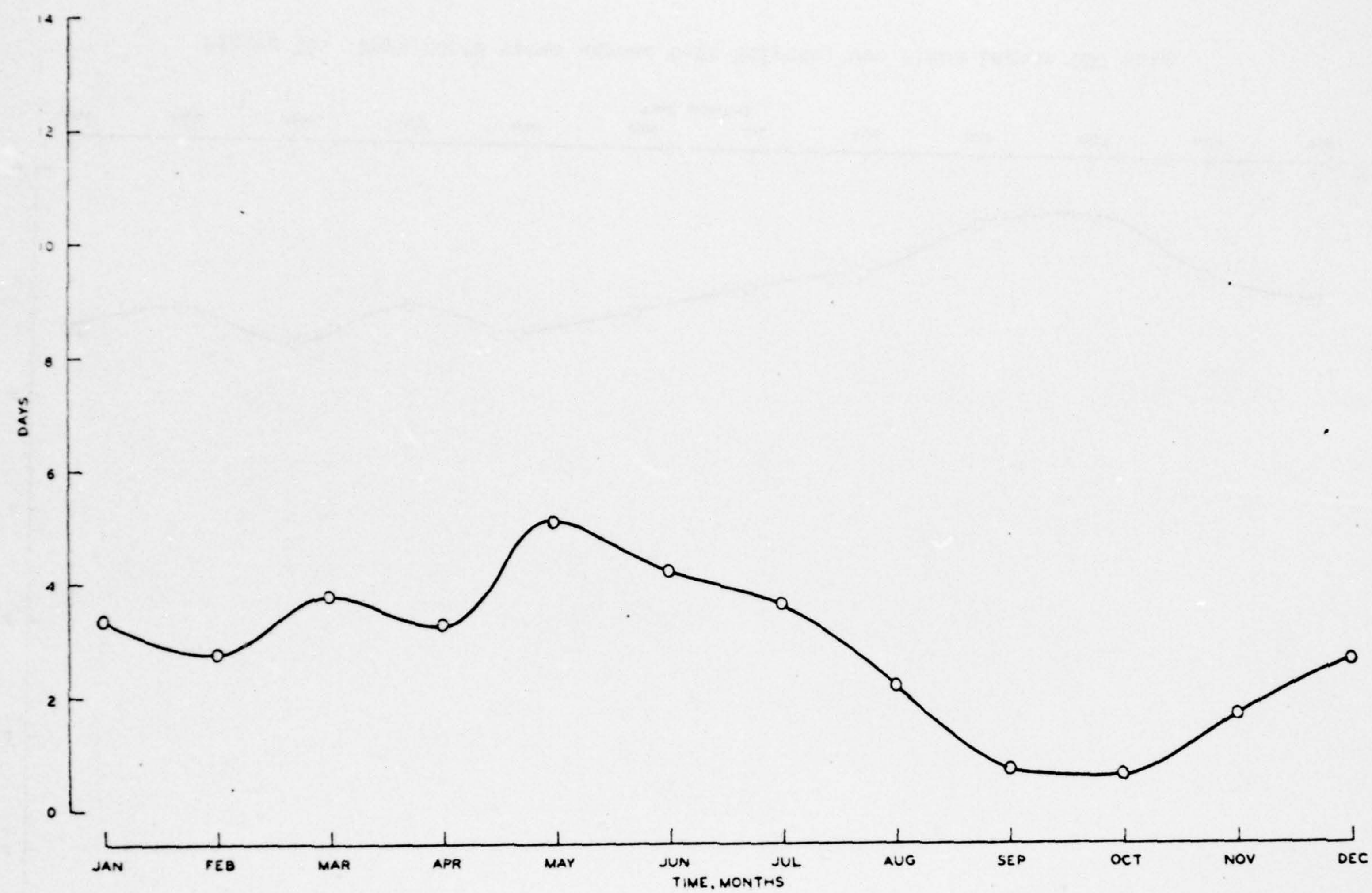

Figure 75. Days/month waves exceed 6-ft heights, Point Buchon LNG site

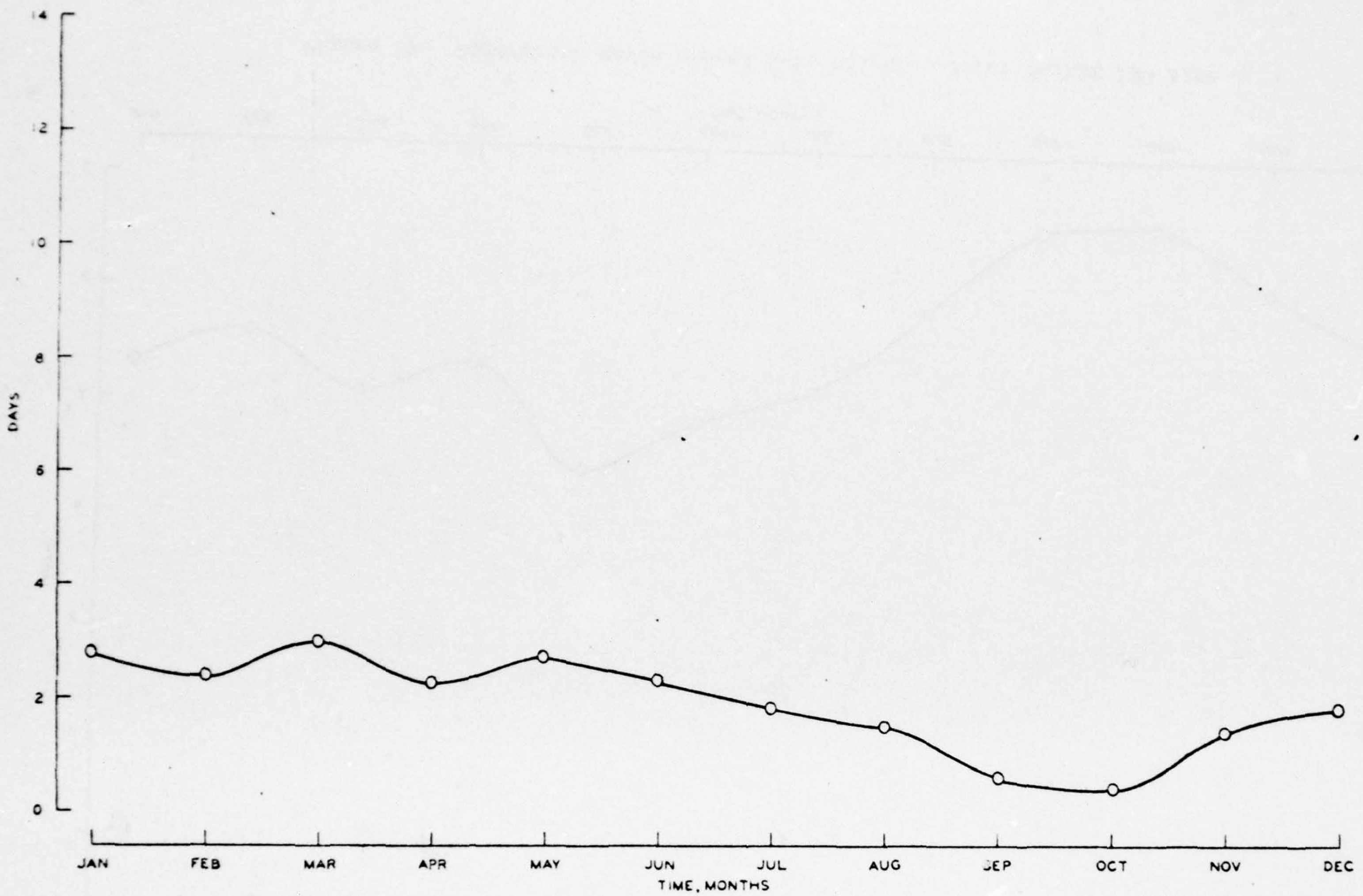

Figure 76. Days/month waves exceed 6-ft heights, Oso Flaco Lagoon LNG site

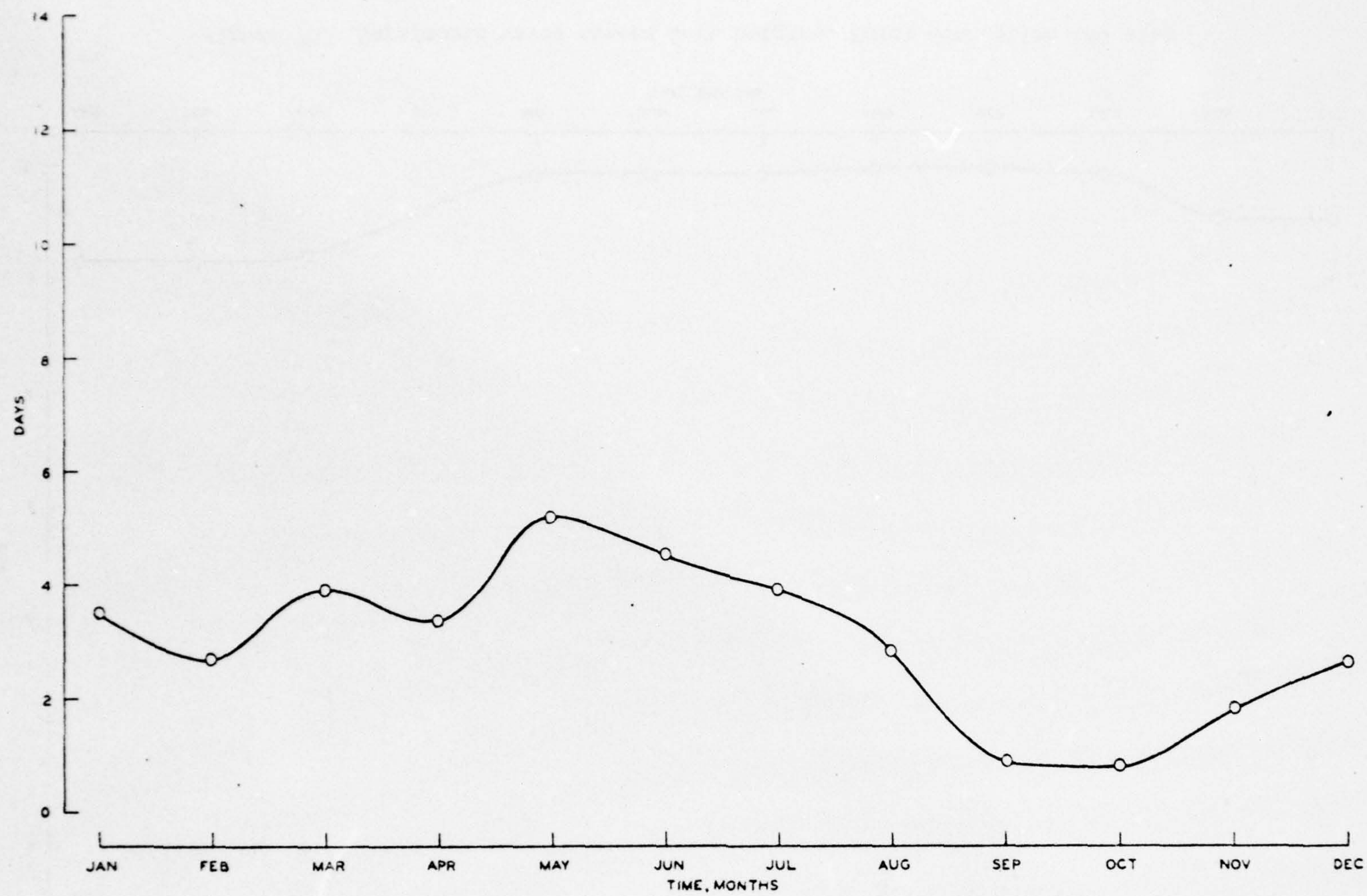

Figure 77. Days/month waves exceed 6-ft heights, Guadalupe Dunes LNG site

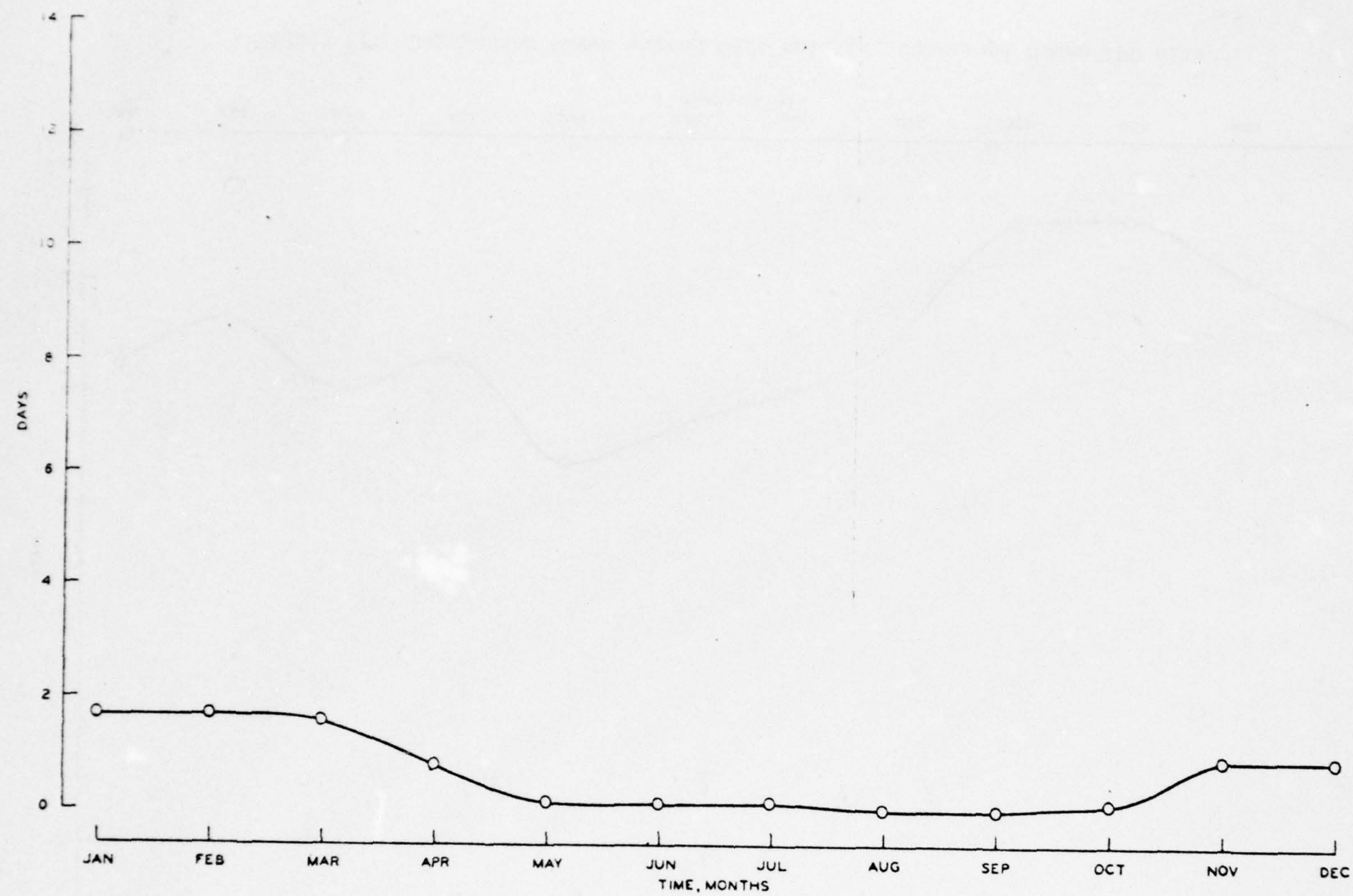

Figure 78. Days/month waves exceed 6-ft heights, Point Conception LNG site

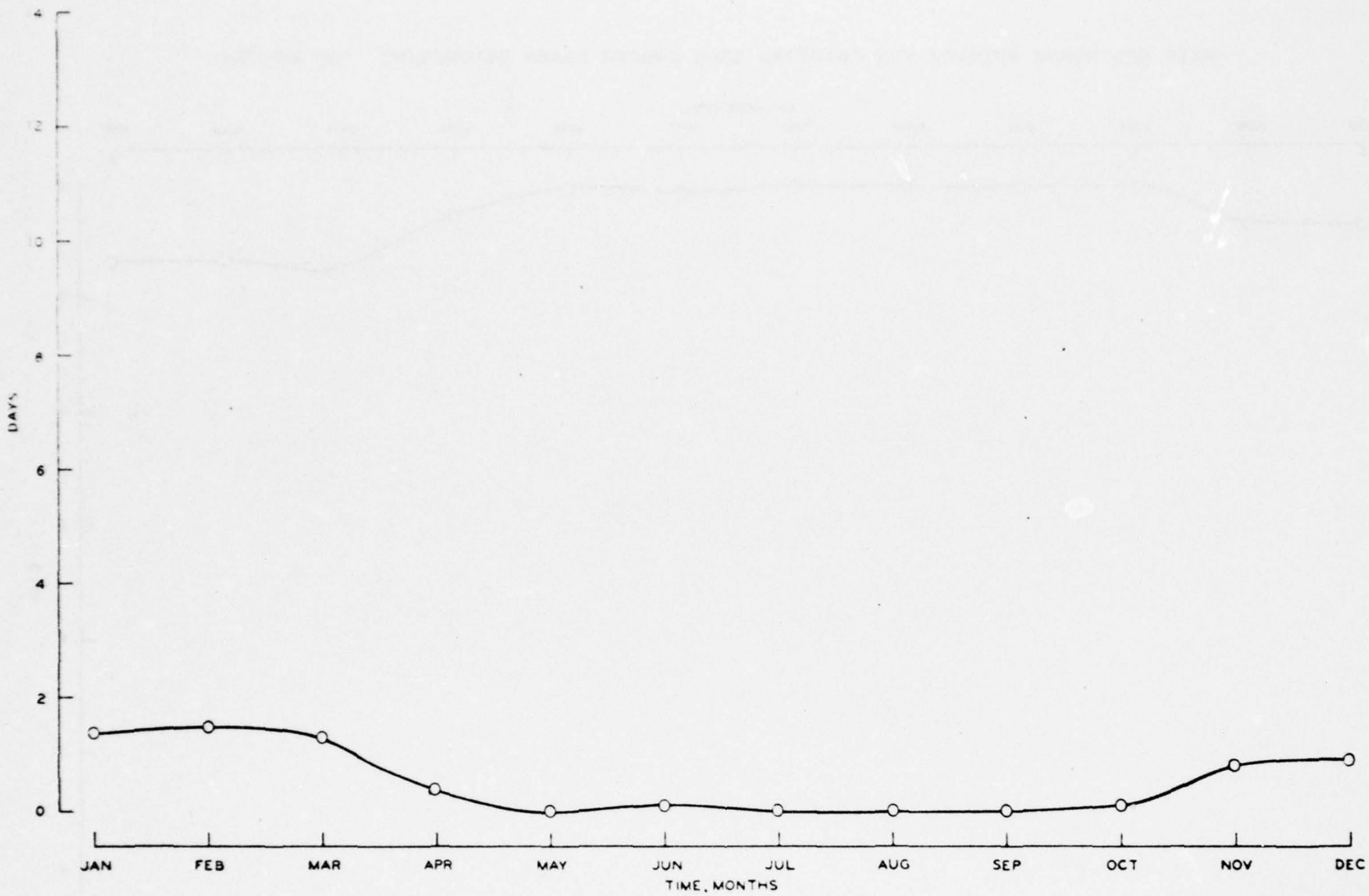

Figure 79. Days/month waves exceed 6-ft heights, Tajiguas LNG site

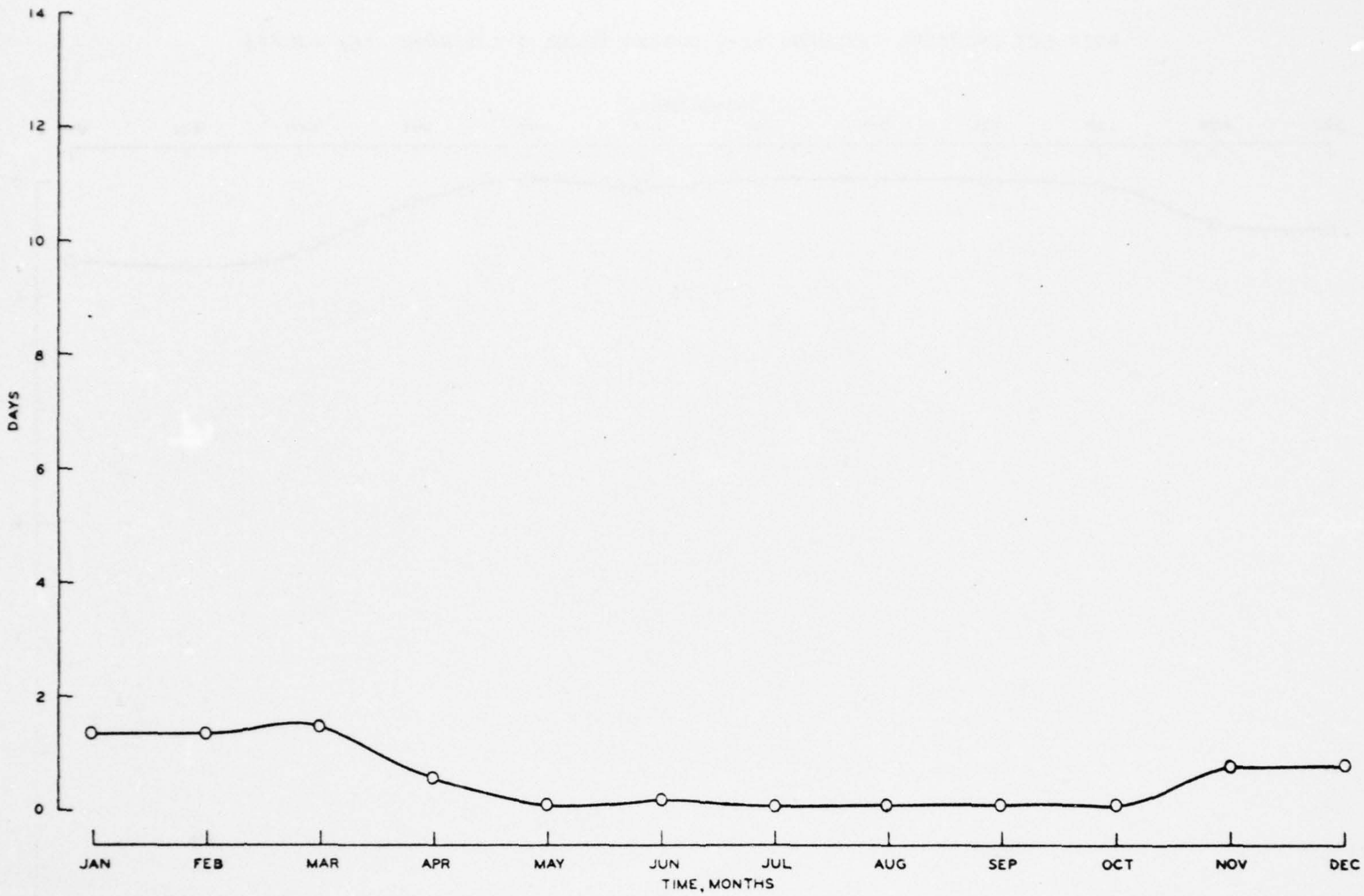

Figure 80. Days/month waves exceed 6-ft heights, Dos Pueblos Ranch LNG site

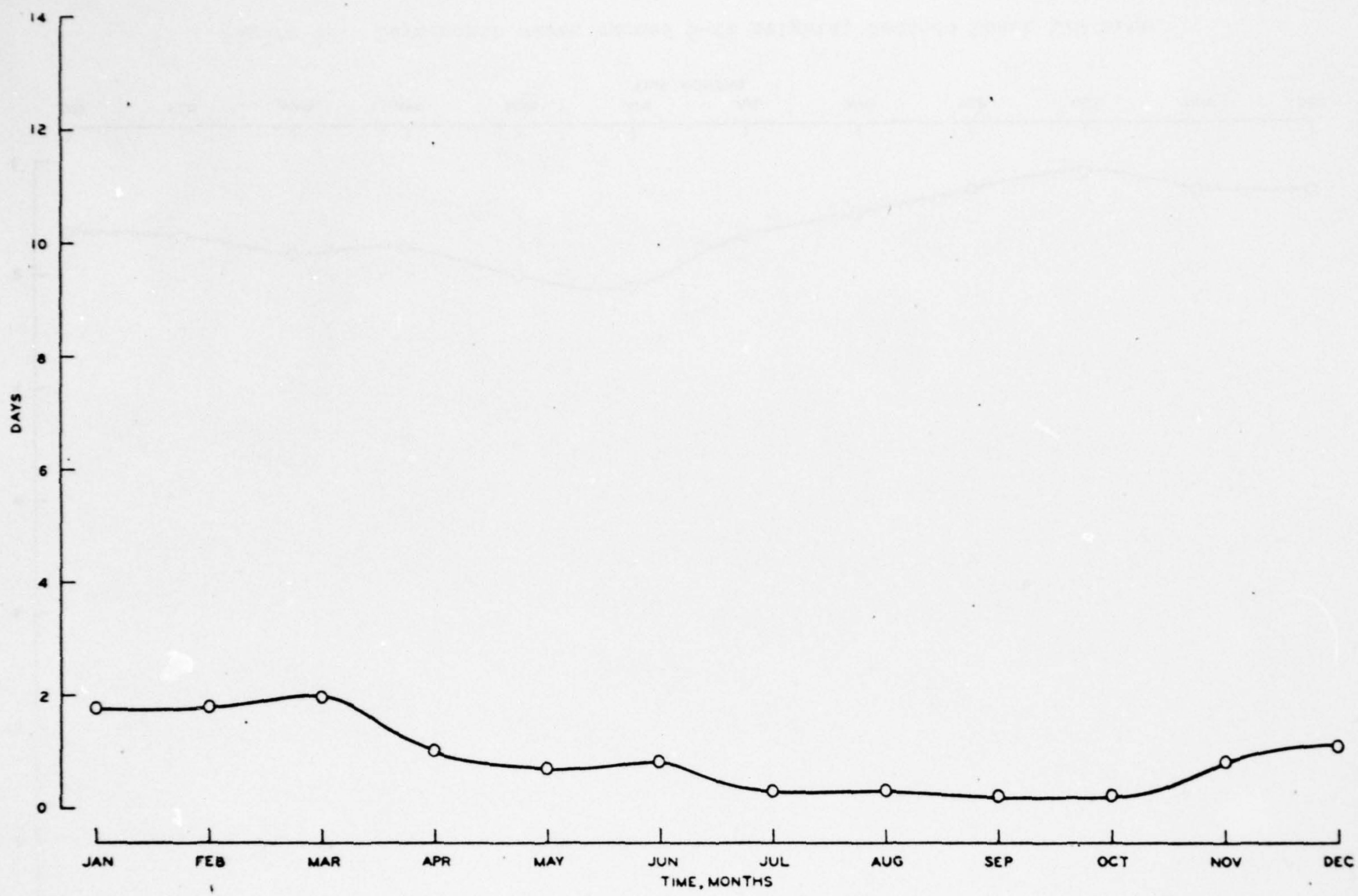

Figure 81. Days/month waves exceed 6-ft heights, Deer Canyon LNG site

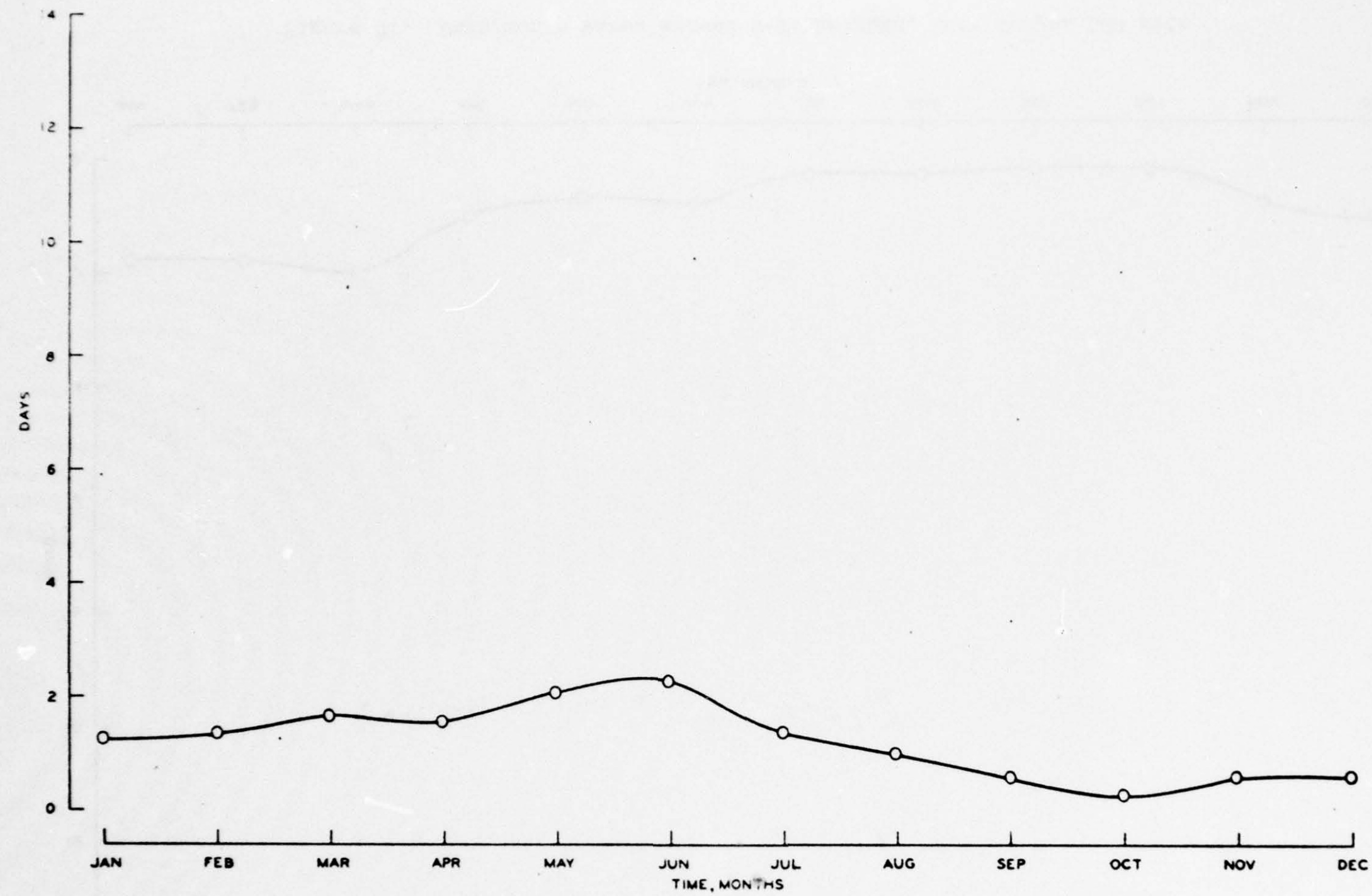

Figure 82. Days/month waves exceed 6-ft heights, Redondo Beach LNG site

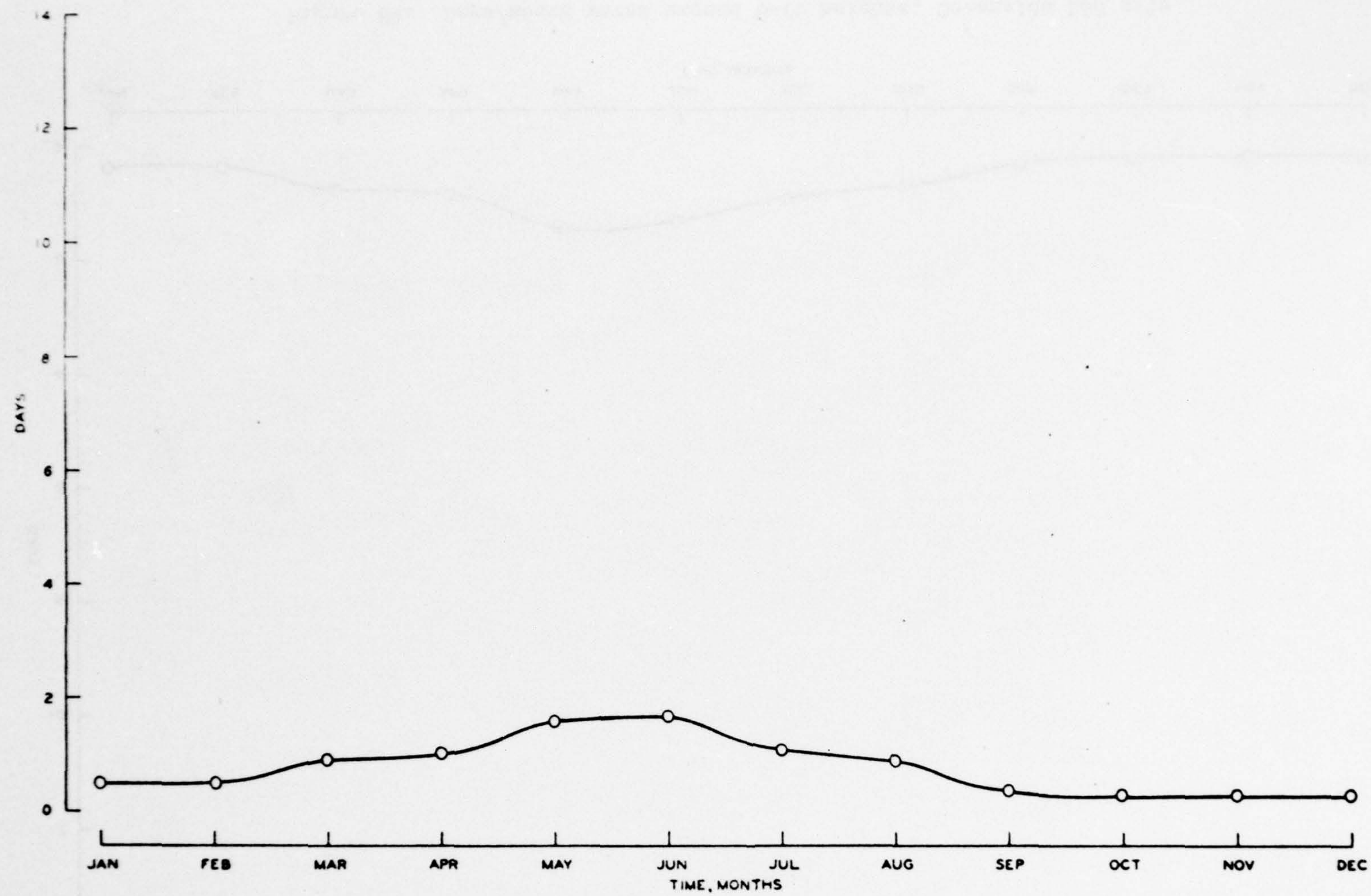

Figure 83. Days/month waves exceed 6-ft heights, Camp Pendelton LNG site

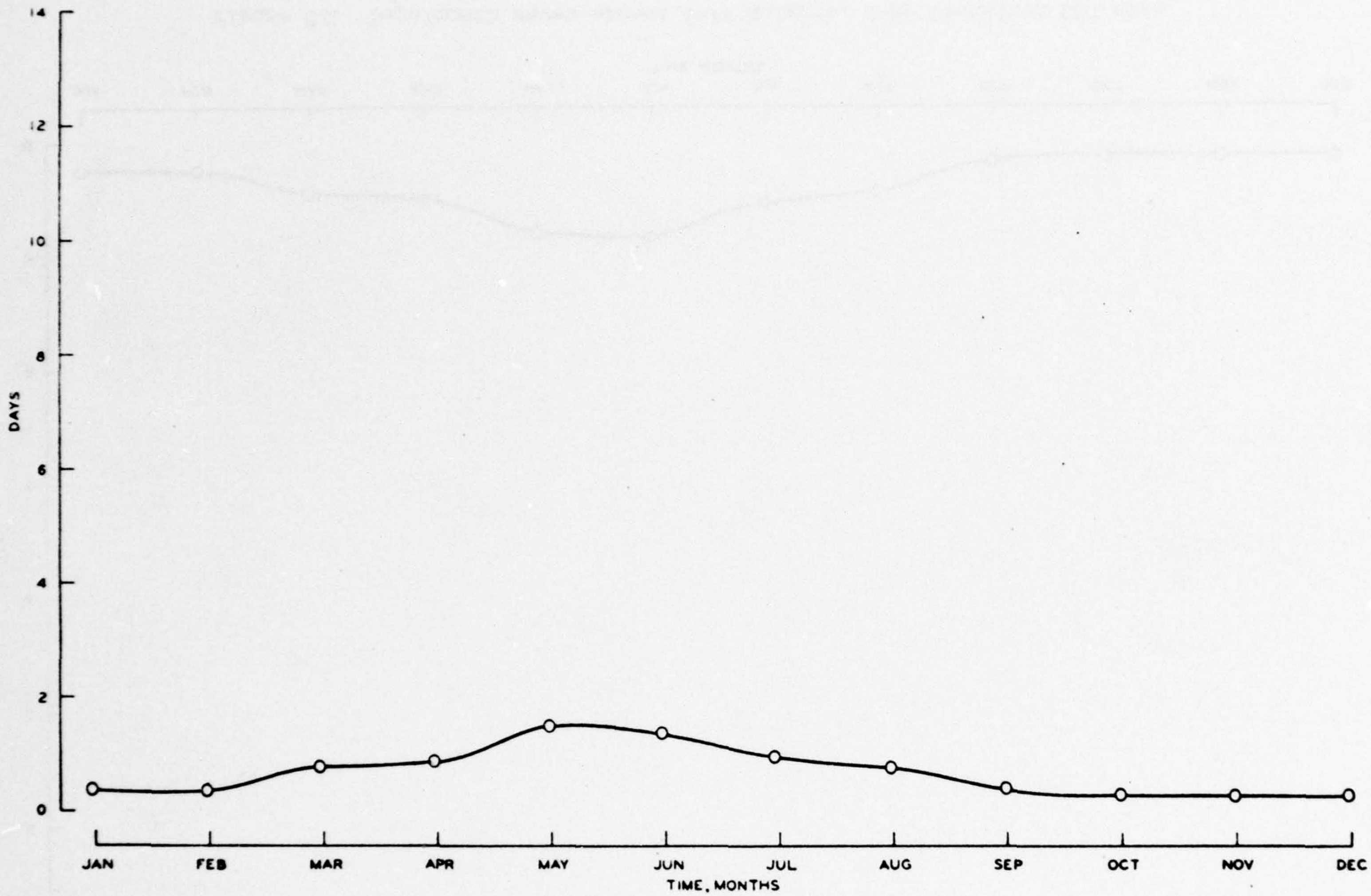

Figure 84. Days/month waves exceed 6-ft heights, Oceanside LNG site

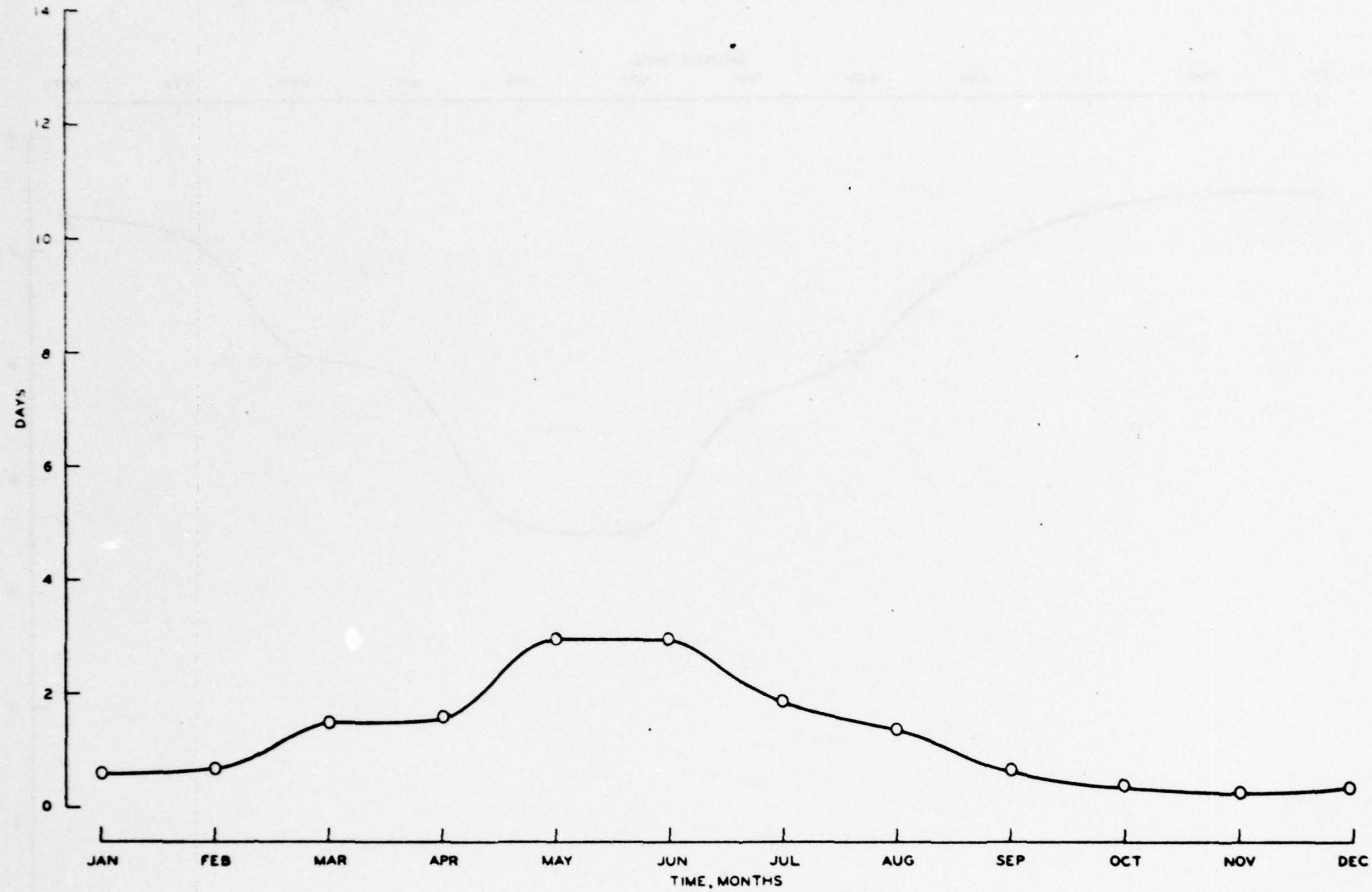

Figure 35. Days/month waves exceed 6-ft heights, Encinitas LNG site

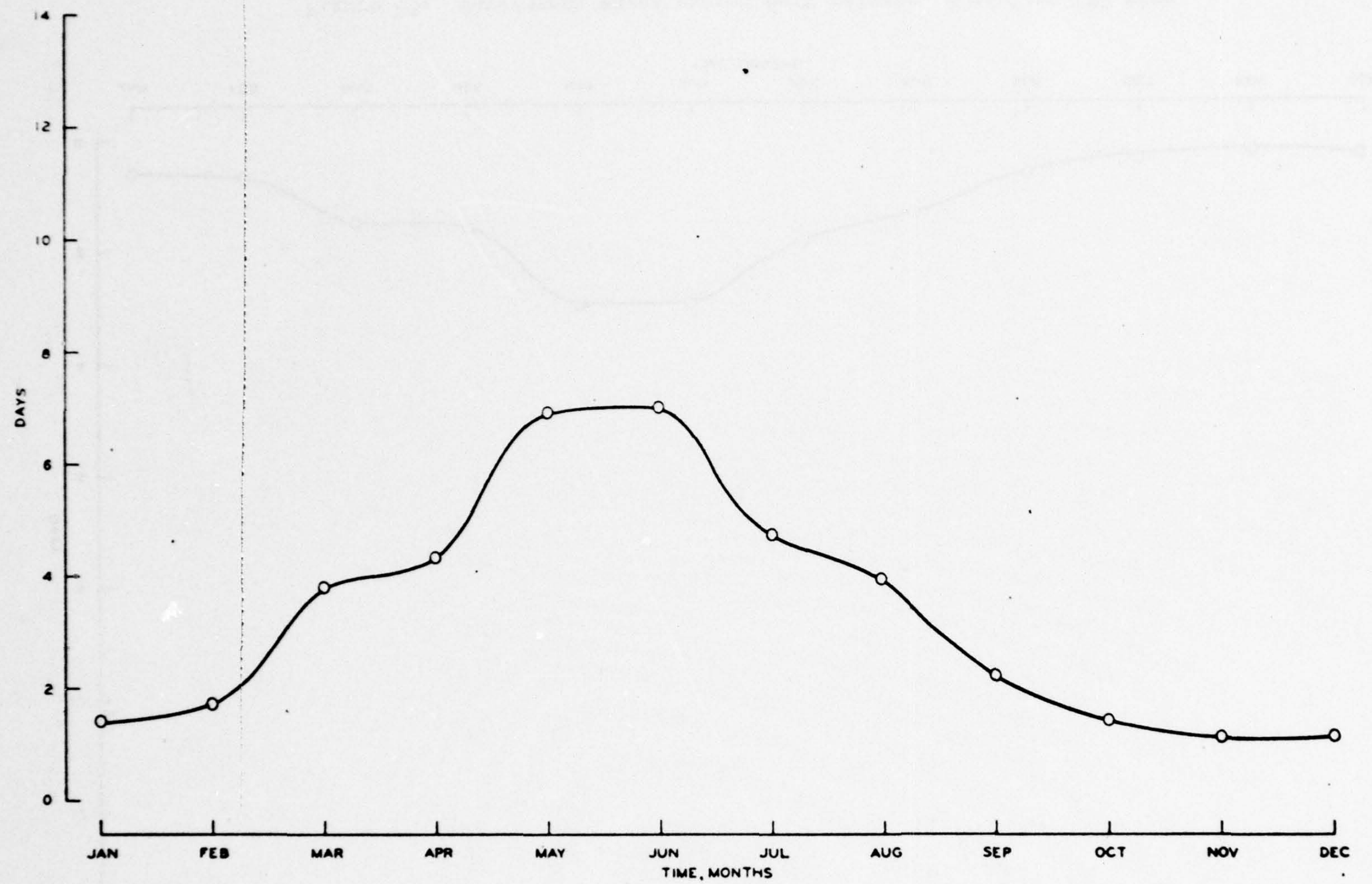

Figure 86. Days/month waves exceed 6-ft heights, Mission Bay LNG site

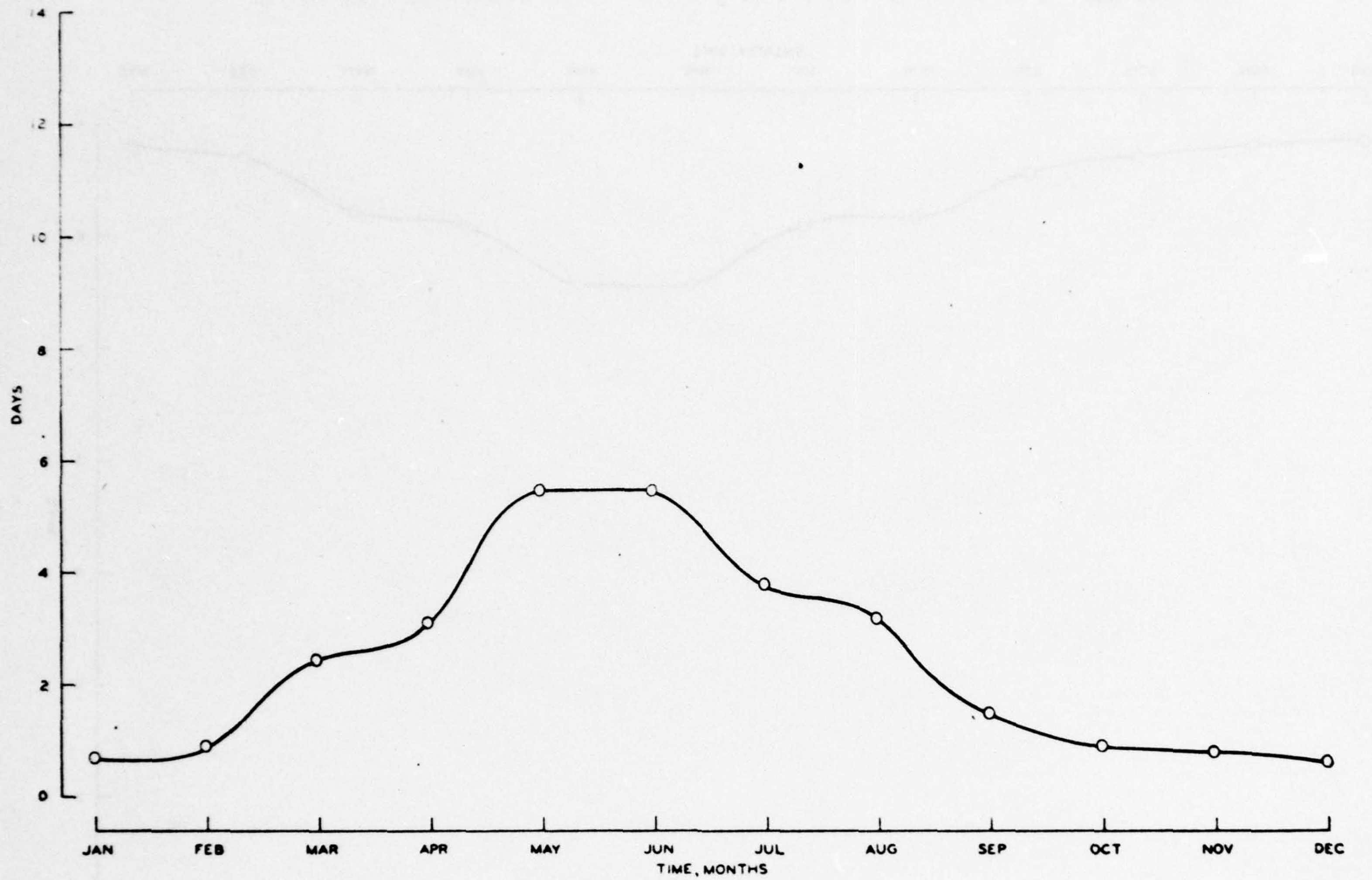

Figure 87. Days/month waves exceed 6-ft heights, Santa Rosa Is. CCC LNG site

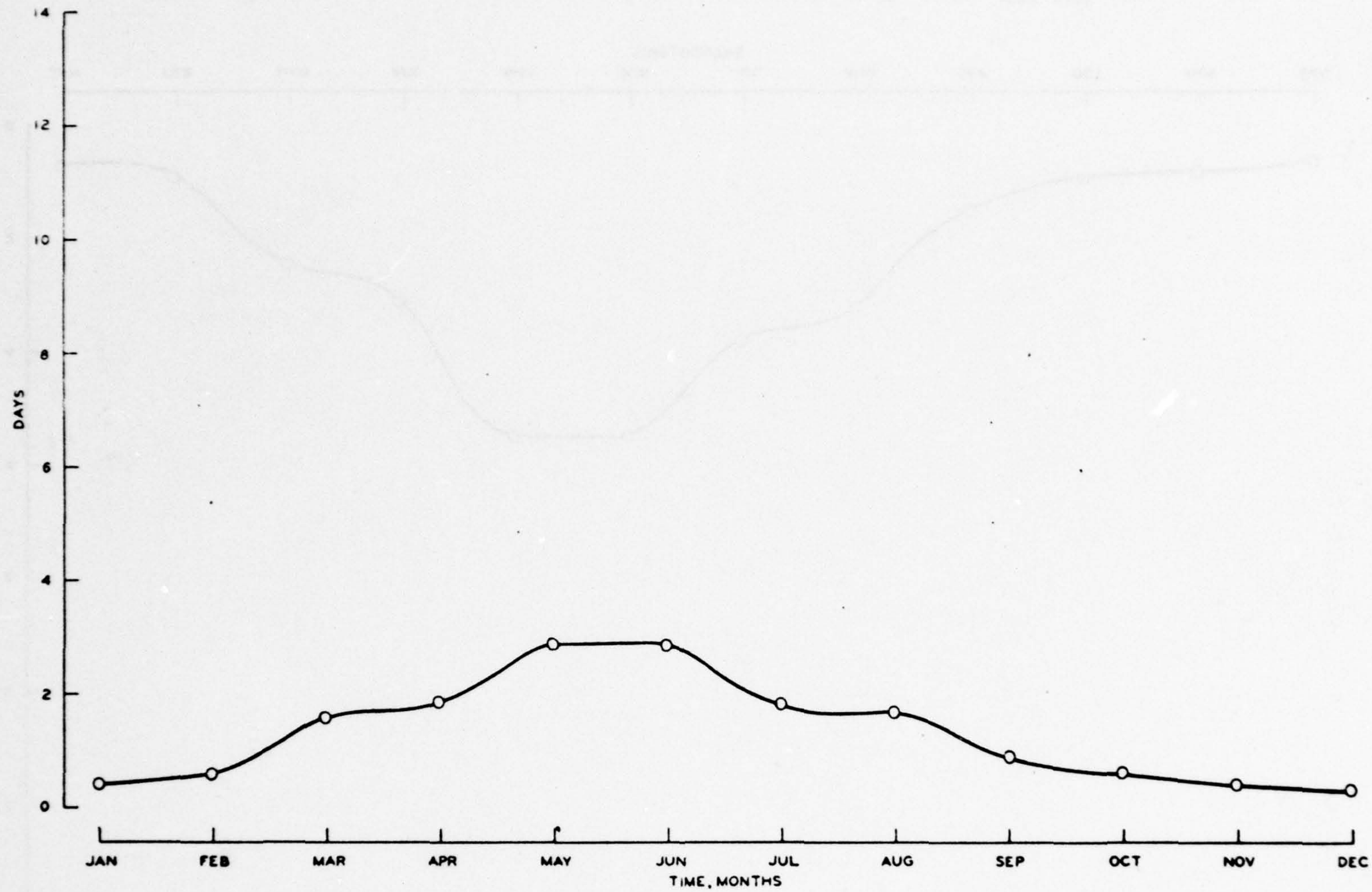

Figure 88. Days/month waves exceed 6-ft heights, Santa Rosa Is. WES LNG site

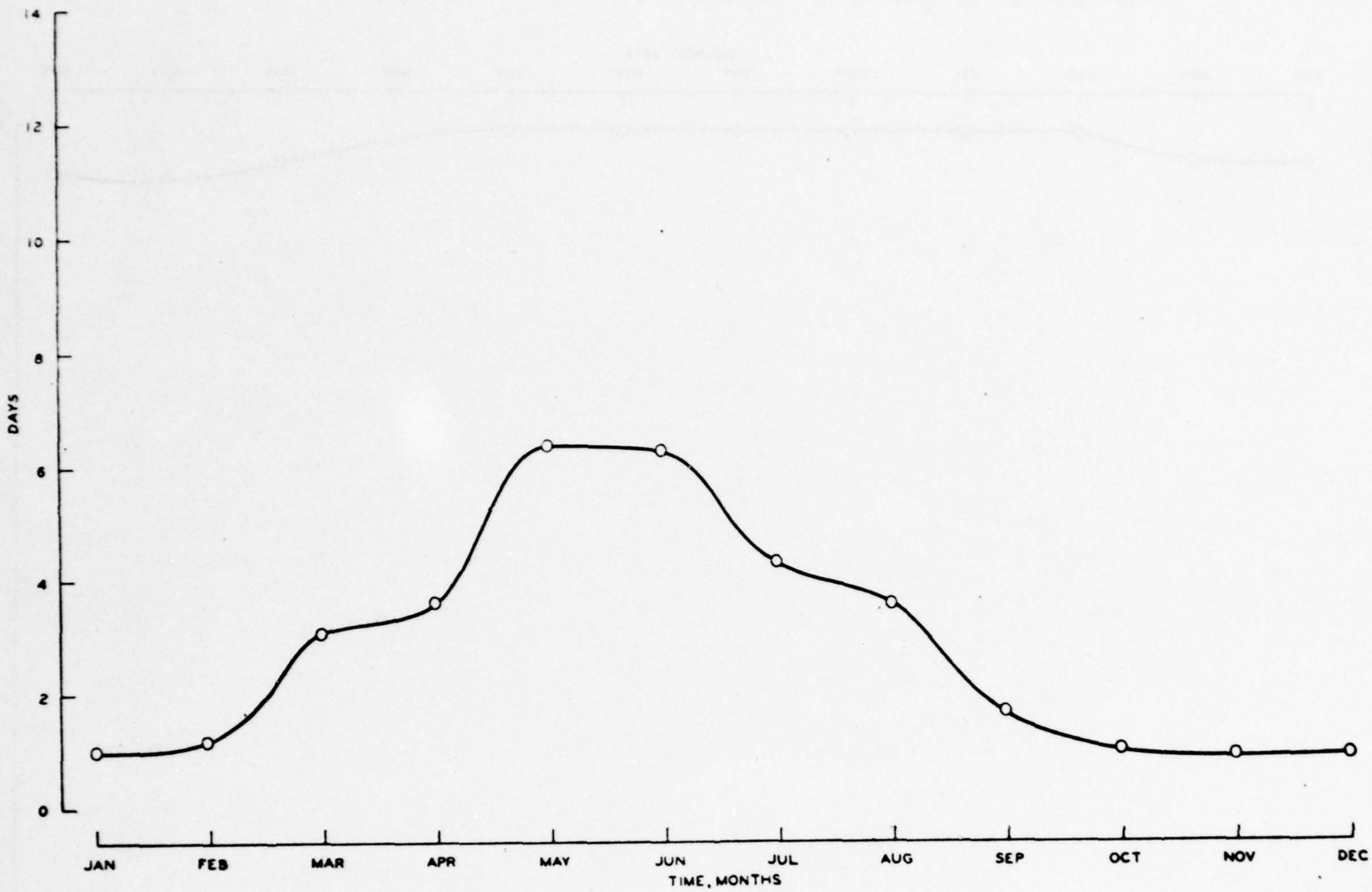

Figure 39. Days/month waves exceed 6-ft heights, Santa Cruz Is. N. LNG site

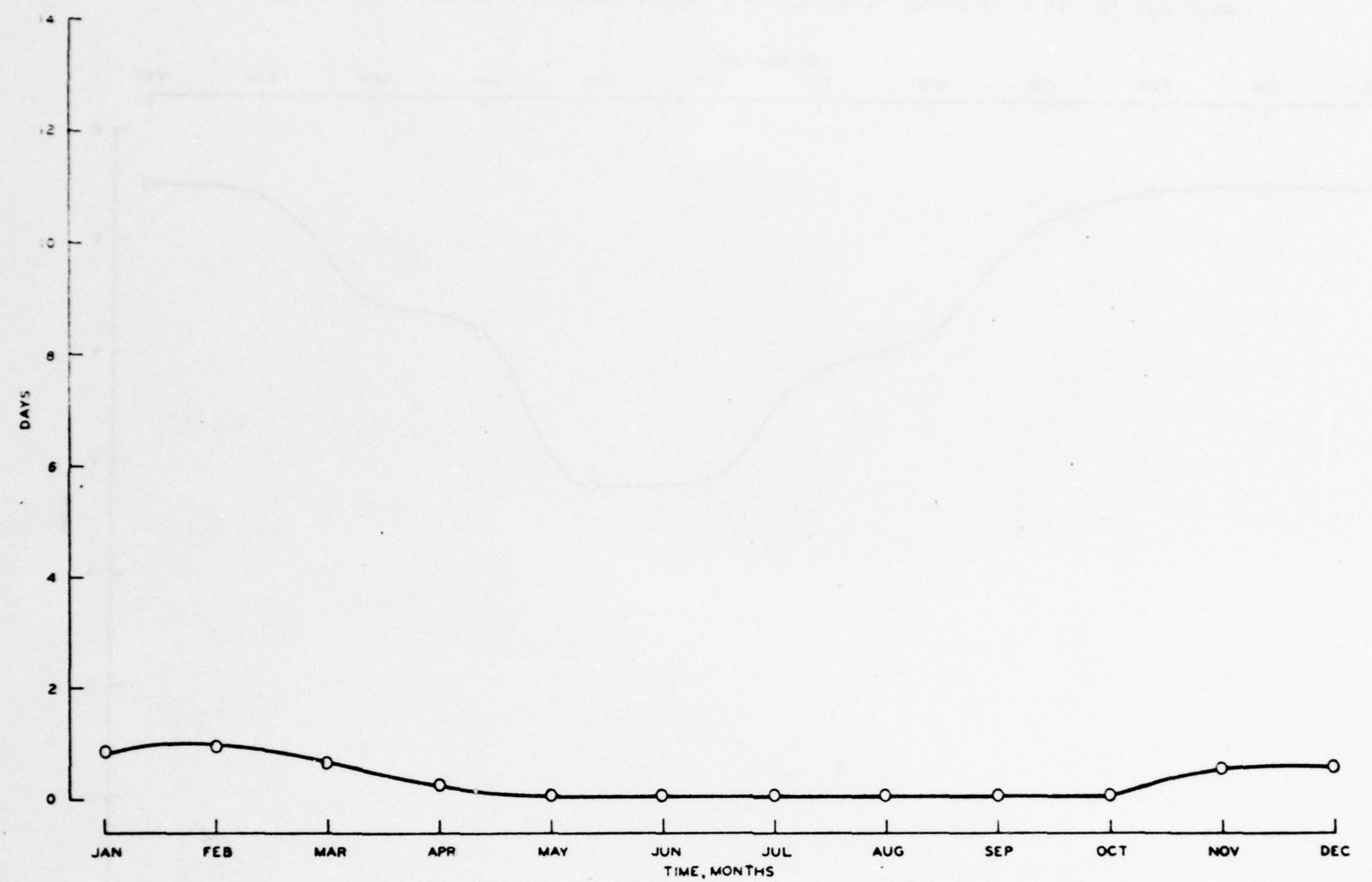

Figure 90. Days/month waves exceed 6-ft heights, Santa Cruz Is. E. LNG site

PART V: OPTIMIZATION TECHNIQUES CRITERIA

56. Delft Hydraulics Laboratory[6] was commissioned by Pacific Indonesia LNG Company to provide scientific and engineering services for the design of the proposed Oxnard marine terminal off Port Huenneme, California. These services were to include: (1) refraction computation to convert offshore wave data into values applicable for the terminal site, (2) study of mooring operations and computations of required tug power, and (3) model tests on hawser and fender forces of the LNG carrier and statistical computations to determine the optimum terminal orientation.

57. Certain questions arose during the conduct of the investigation for which there are, of course, no absolute answers. For example, the basic data for the westerly waves utilized in the statistical computations were drived from a study of the wind and wave regime at Port Huenneme by Oceanographic Services, Inc.[7] The winter and summer data had been averaged and were considered by OSI to be "average" year conditions. It was assumed by Delft that 50 percent of the westerly waves came from the sector 270°-277^{0} and 50 percent came from the sector 278°-285°. This separation was deduced because the refraction was different for those two sectors.

58. After comparison of the data of OSI with those of Kent[1], it appeared that the waves reported by Kent were higher. Kent had based his data on station 6 of the National Marine Consultants work, and NMC had stated that at station 6 the west direction category was extended to include 290° and that for west-northwest swell arriving at angles greater than 290°, a westerly component was computed and included in the statistics. The Delft researchers hypothesized that this probably explained the difference between the wave heights of OSI and those of Kent, and after consultation with the contractor decided to use the smaller, less conservative, values of OSI.

59. Based on Marine Advisers work during the months of May through October, swell from the southern hemisphere reaches the coast of California. The OSI report does not consider this swell because

of its low height. However, this swell is very important because of its long period (12-20 seconds). Kent had based his study on Marine Advisers compilation. This time it was decided to use the more conservative statistics of Kent.

60. At the time of the preparation of the Delft report, waves were being recorded with a buoy by OSI at the Oxnard site. It was recommended that these recordings be continued for at least a year in order to determine whether the wave data used in the statistical computations were representative or not. Special attention should be paid to the southern hemisphere swell during the months of May to October, and to waves arriving at the site from more than one direction.

61. Physical model tests were performed using a scale model of an LNG tanker subjected to the statistical wave climate refered to above. The wave heights and wave directions for each cumulative frequency distribution had been corrected for shoaling and refraction. For a certain terminal orientation the wave direction for each frequency distribution was related to a certain relative angle (relative angle between the wave direction and the terminal heading). Each frequency distribution was also related to a certain wave period. At a certain terminal heading at each frequency distribution, a certain height could be allocated via the angle and the period. The percentages of exceedance of the heights gave the downtime for the chosen terminal heading. In this way it is possible to compute the downtime for all terminal orientations. The optimization curves produced by this Delft study are presented in Figure 1, and constitute the criteria to be used in this study of 26 potential LNG terminal sites.

62. The procedure for applying the optimization curves of Figure 1 at each potential site consisted of first optimizing the terminal heading. This was accomplished by arbitrarily but selectively choosing a trial heading, applying the criteria from the optimization data, and computing the downtime associated with this heading. Next, a slightly different heading was chosen at the same site, the optimization curves were applied, and the downtime was computed for this second trial

heading. This procedure was continued until the optimum terminal heading had been ascertained, and the downtime was determined.

63. It became rapidly apparent during the optimization operation that the optimum heading of the terminal would be into the direction of the majority of large wave approach. Thus the problem of optimizing the terminal heading was expedited considerably, and the trials necessary to produce the minimum amount of downtime when the optimization curves were applied was reduced to a minimum also, usually two to three trials.

64. For most of the sites north of Point Conception, the optimum terminal heading is in a northwesterly direction. Thus, southern hemisphere swell approaches these terminals at a large angle, on the order of 50°-90°. The allowable wave height for swell periods (15-19 seconds) approaching at these large angles is around 3 ft. Hence, southern hemisphere swell between 3 and 4 ft in height must be accounted for in application of the optimization process. Concern arises over the absence of waves of these magnitudes during the month of June, but the effect on the overall analysis is minimal. Those sites in the extreme southern part of the state tend to be oriented in a northwesterly direction, also, and thus receive a significant amount of southern swell at large angles in excess of the allowable criterion. This is not especially true for those sites north of the channel islands, since they are oriented generally southwest and can tolerate higher waves from the south. At the same time, however, those southward oriented terminals are subjected to swell heights exceeding the allowable criterion from the extreme northwest. A trace of northern swell occurs in most cases, but it is often so minimal that its effect on the total downtime is really inconsequential.

65. The results of the optimization computations for the 26 potential LNG terminal sites are presented for sea, northern swell, and southern swell, in Tables 1 through 26, and displayed graphically in Figures 91 through 116.

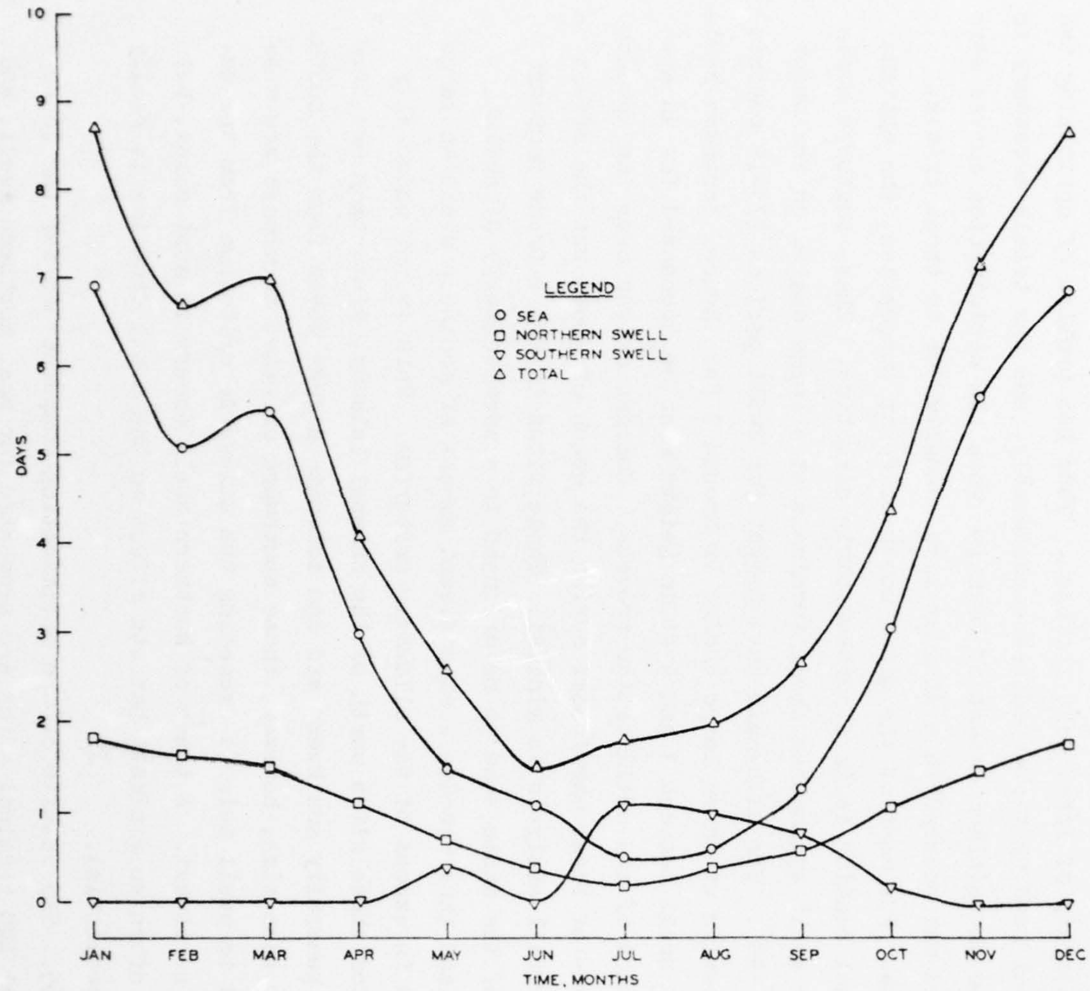

Figure 91. Days/month waves exceed optimization criteria, Crescent City LNG site

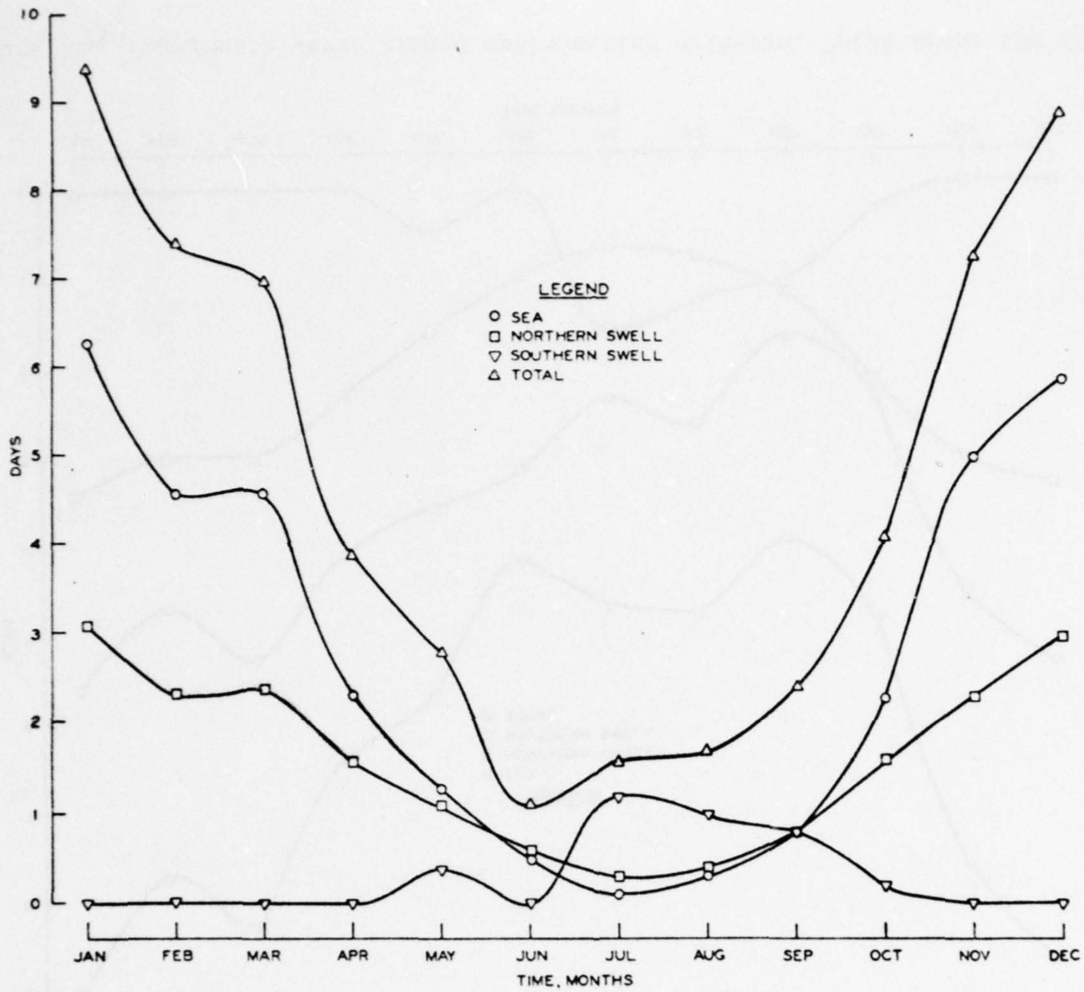

Figure 92. Days/month waves exceed optimization criteria, Point Delgada LNG site

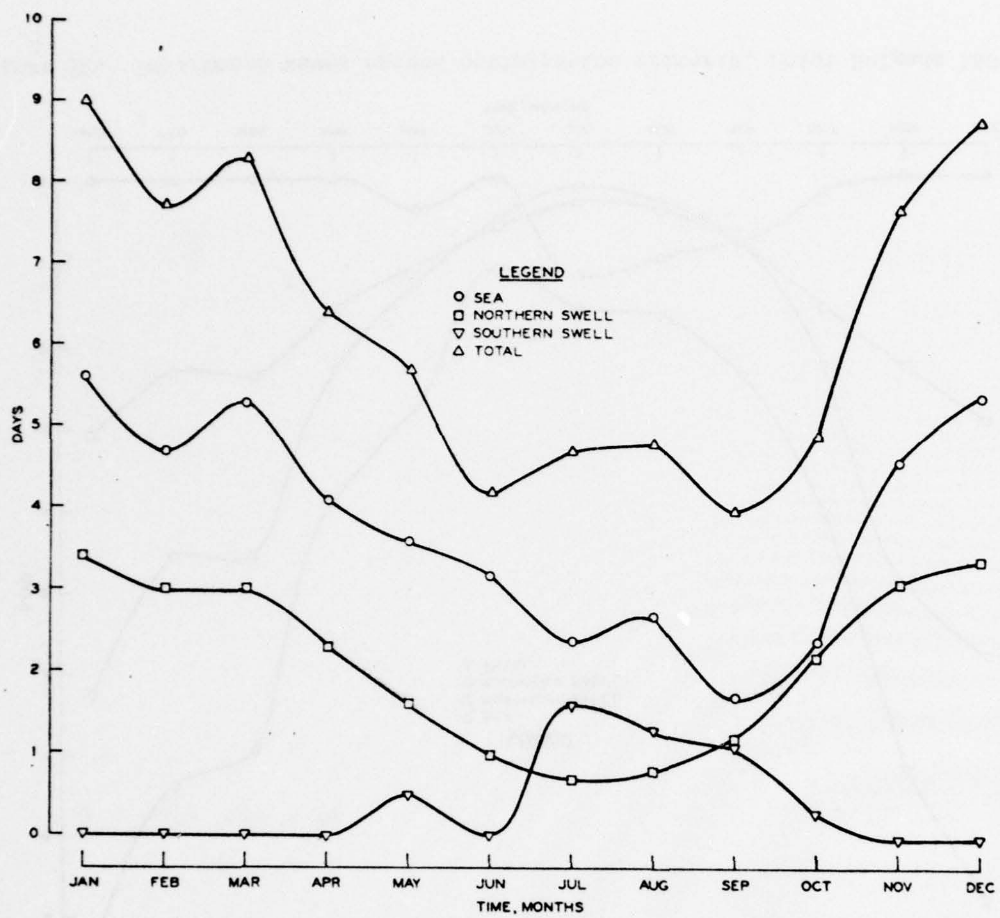

Figure 93. Days/month waves exceed optimization criteria, Point Arena LNG site

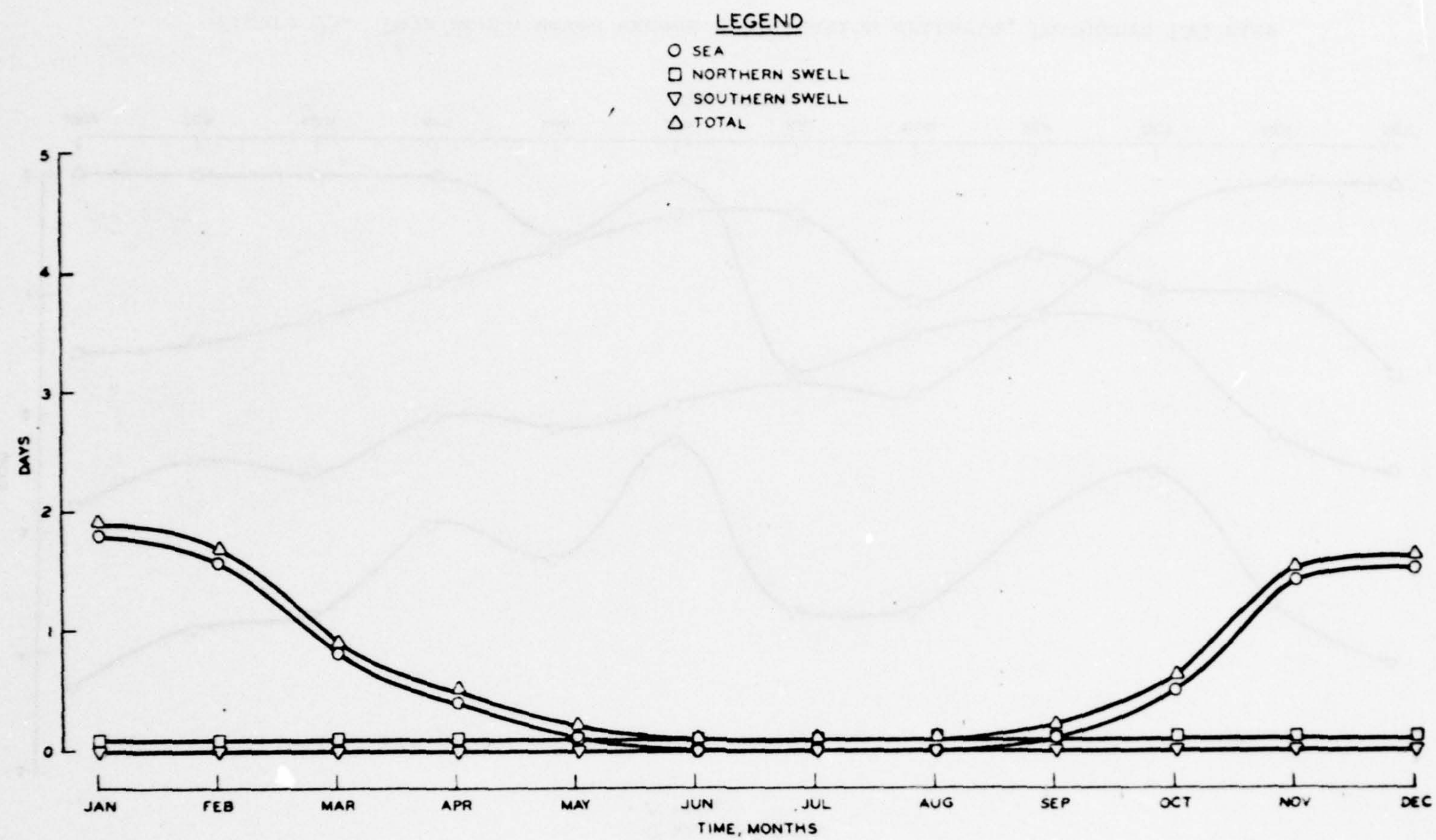

Figure 94. Days/month waves exceed optimization criteria, Point Reyes LNG site

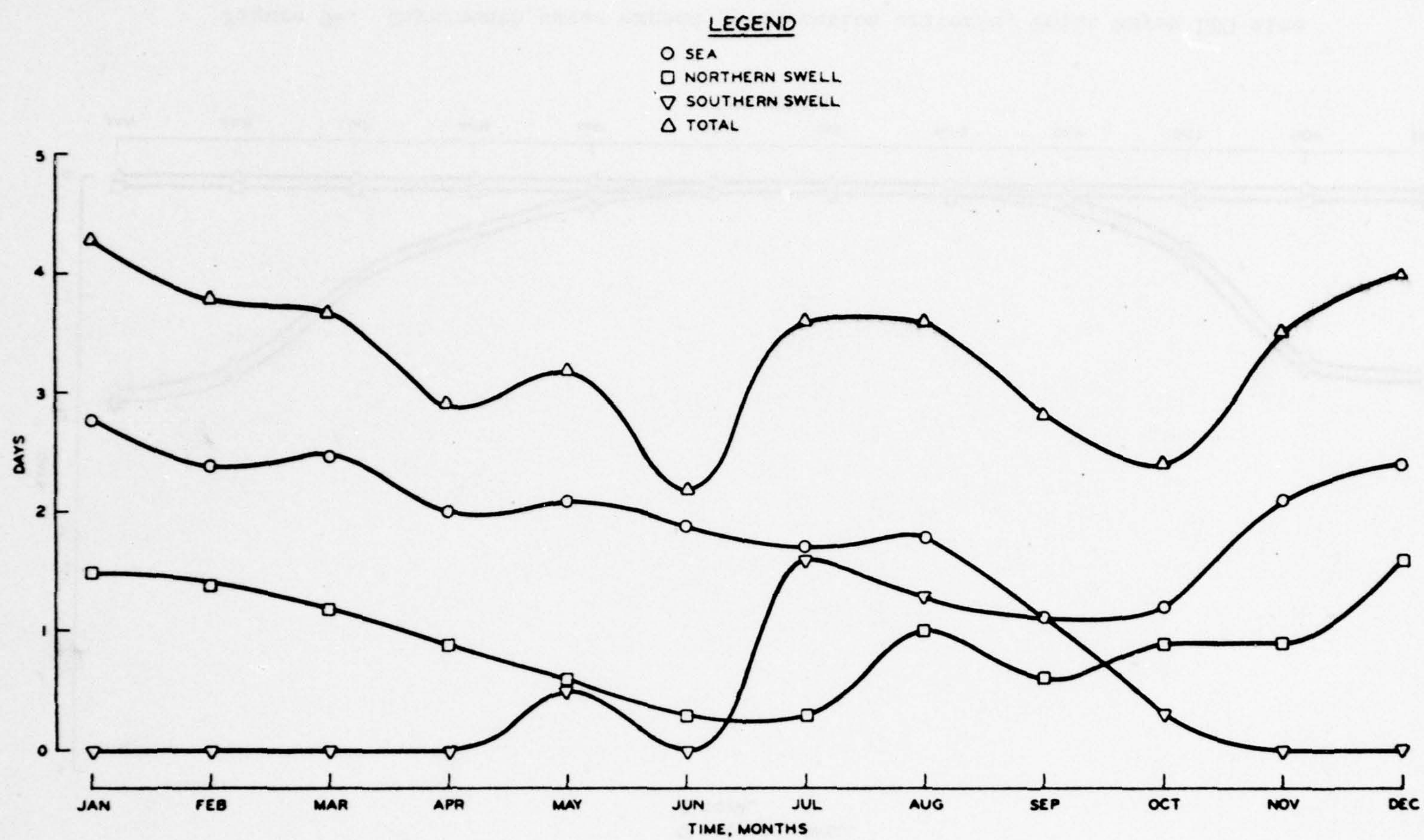

Figure 95. Days/month waves exceed optimization criteria, Davenport LNG site

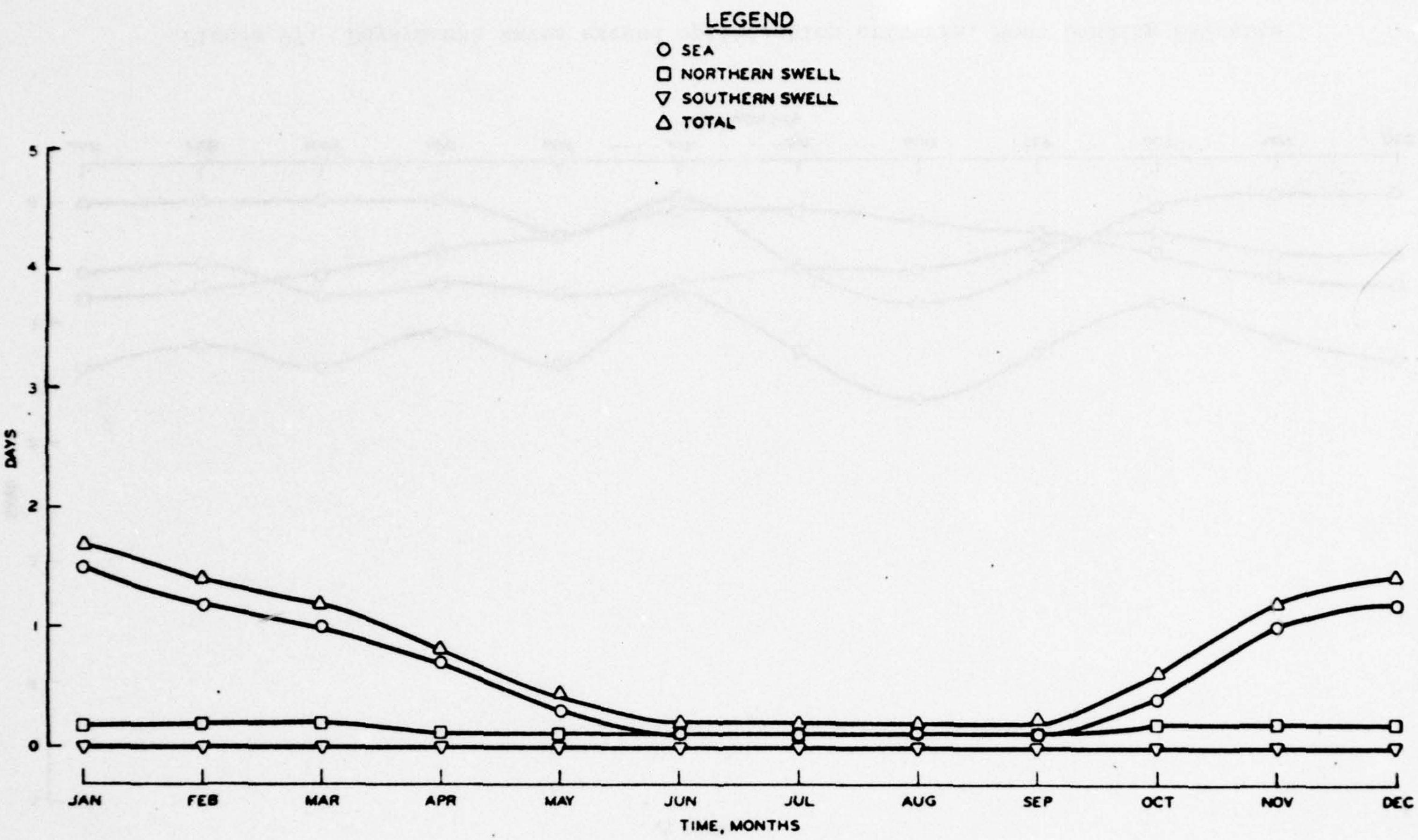

Figure 96. Days/month waves exceed optimization criteria, Soquel Point LNG site

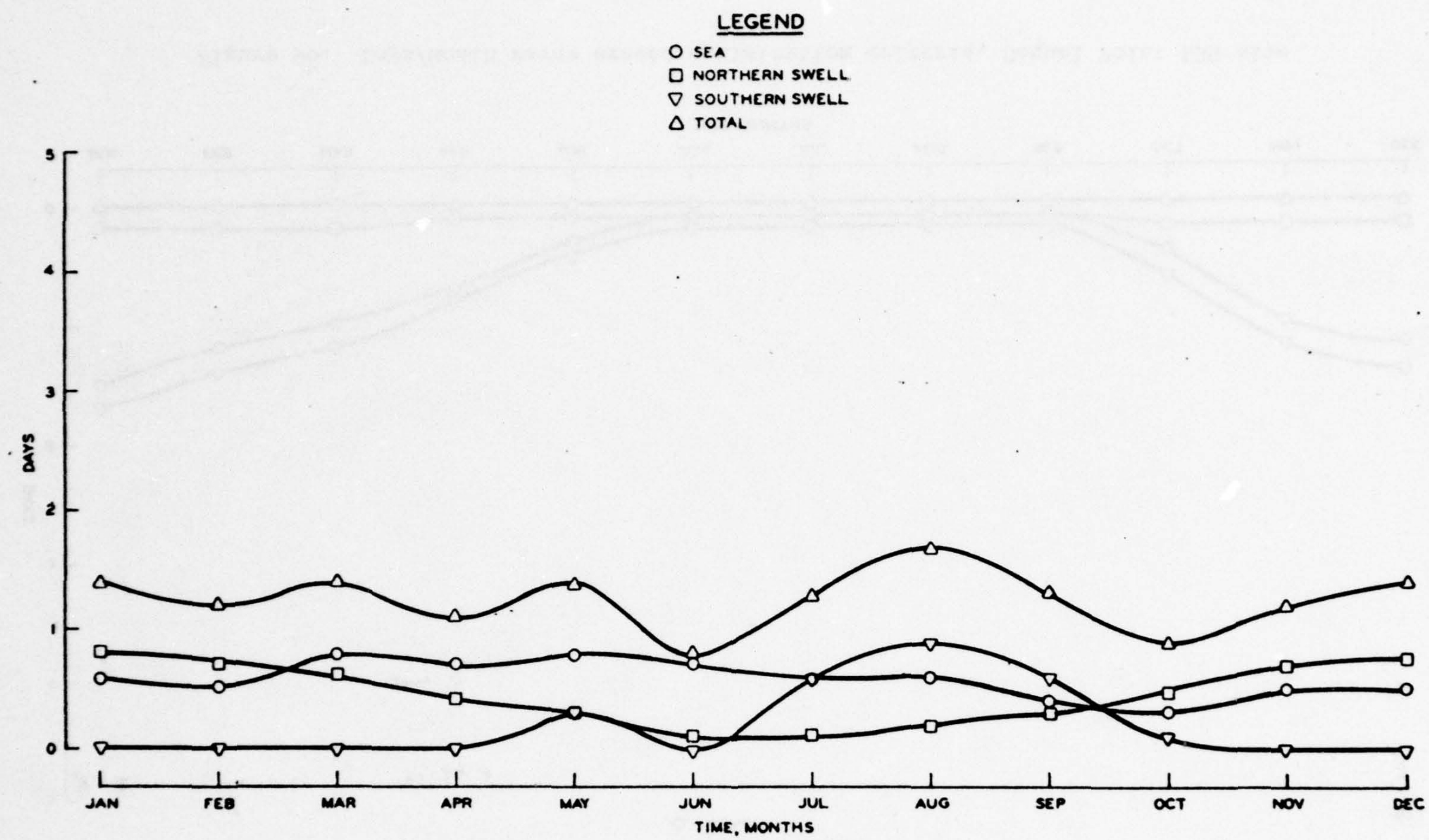

Figure 97. Days/month waves exceed optimization criteria, Moss Landing LNG site

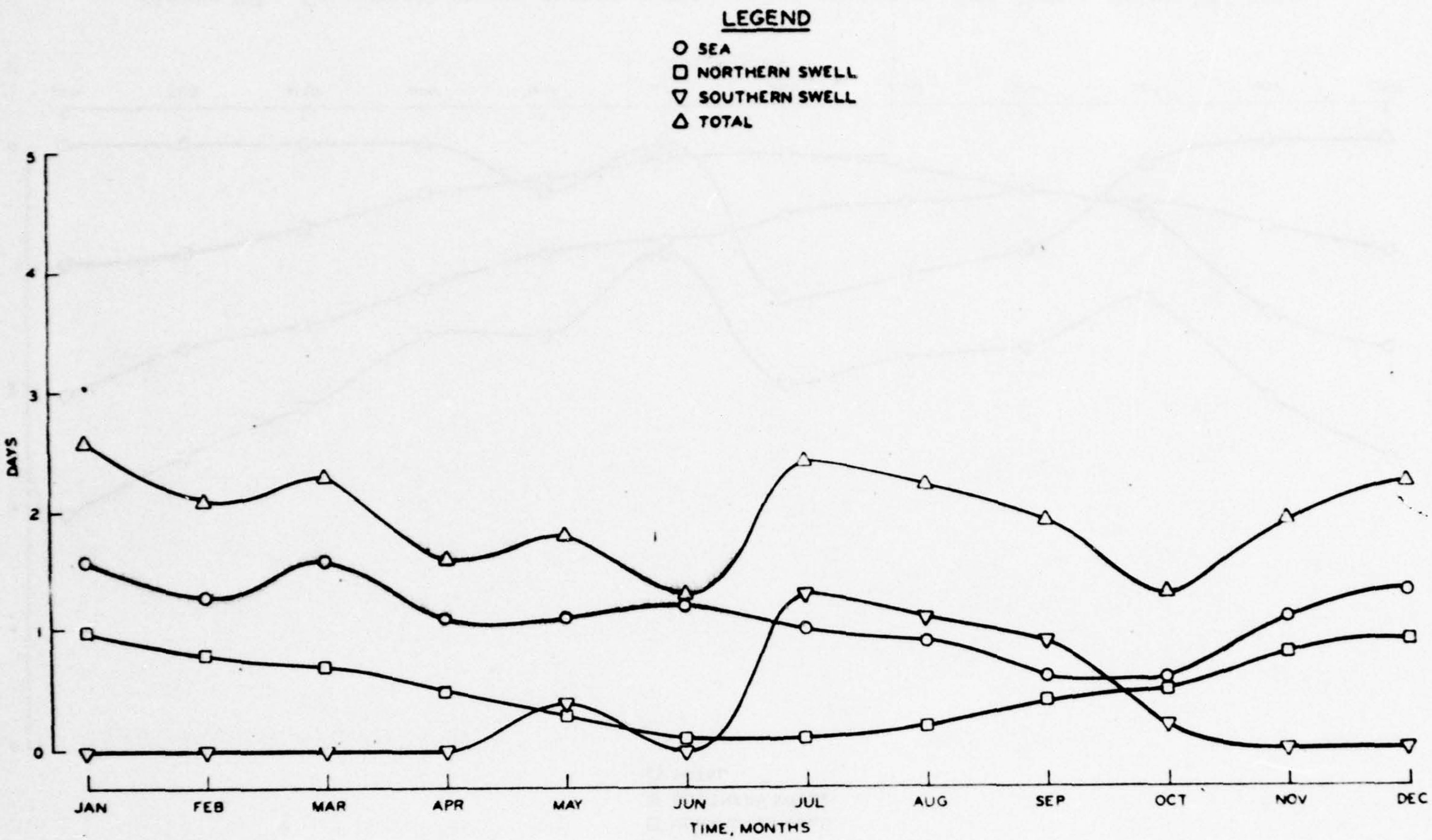

Figure 98. Days/month waves exceed optimization criteria, Partington Point LNG site

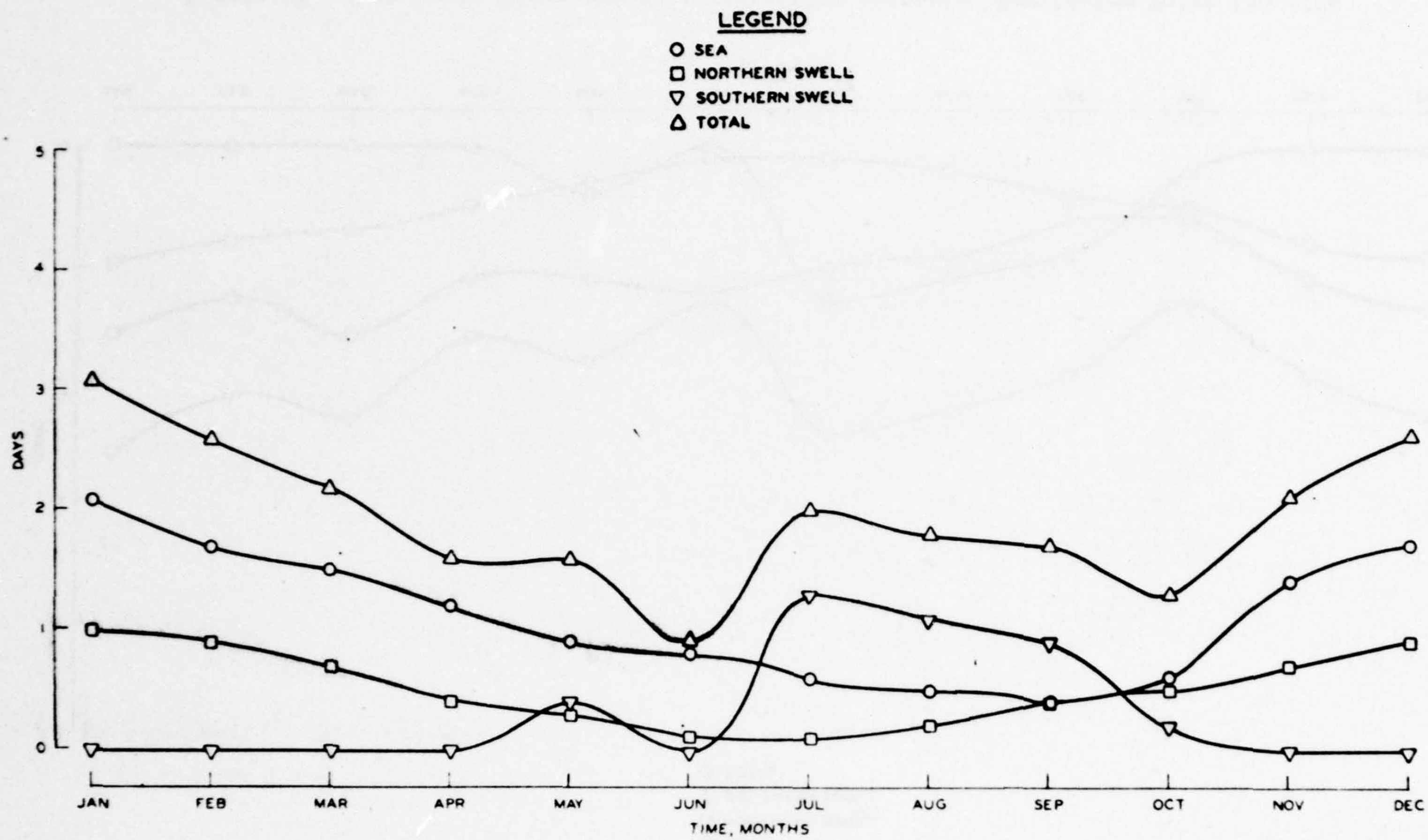

Figure 99. Days/month waves exceed optimization criteria, San Simeon Point LNG site

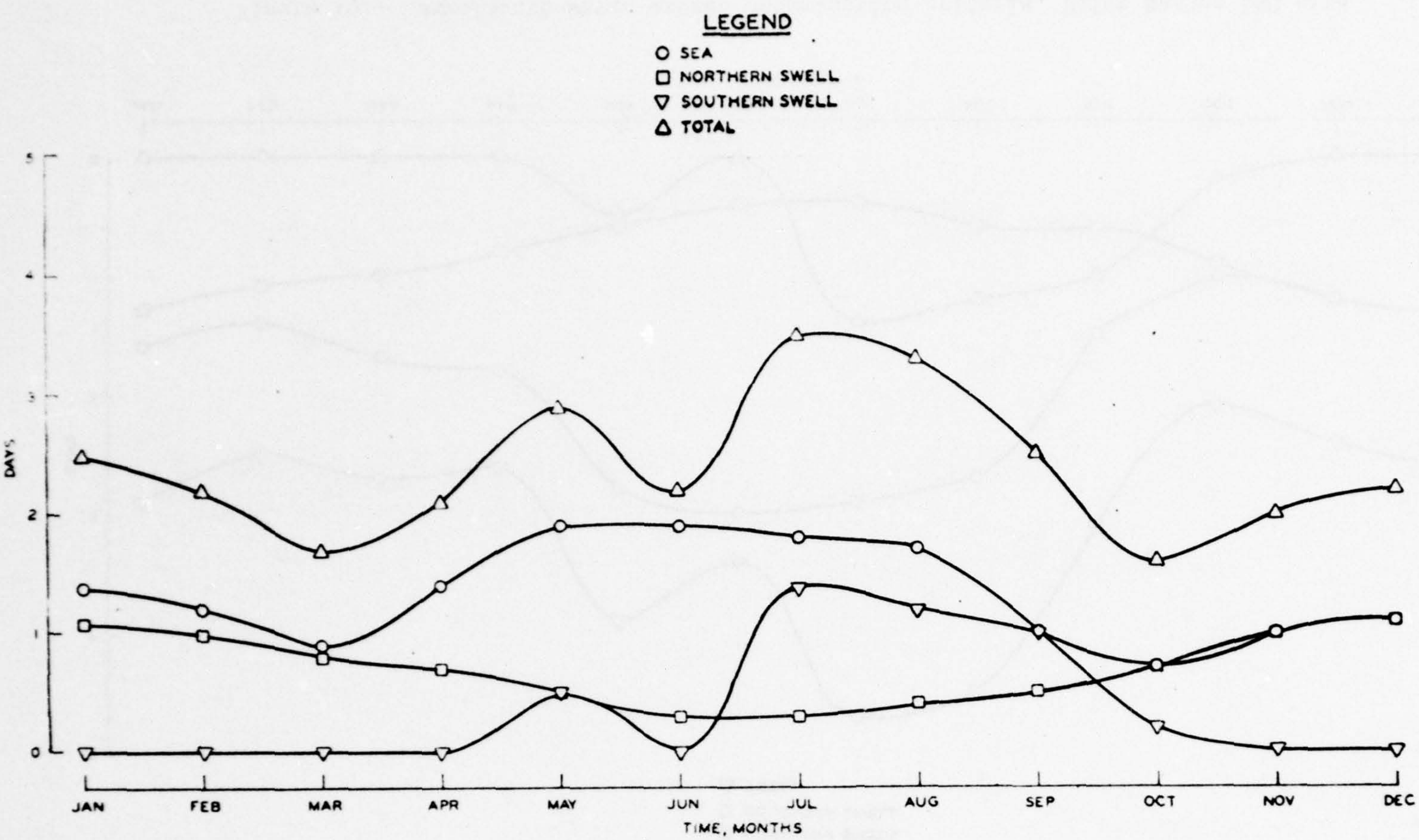

Figure 100. Days/month waves exceed optimization criteria, Point Estero LNG site

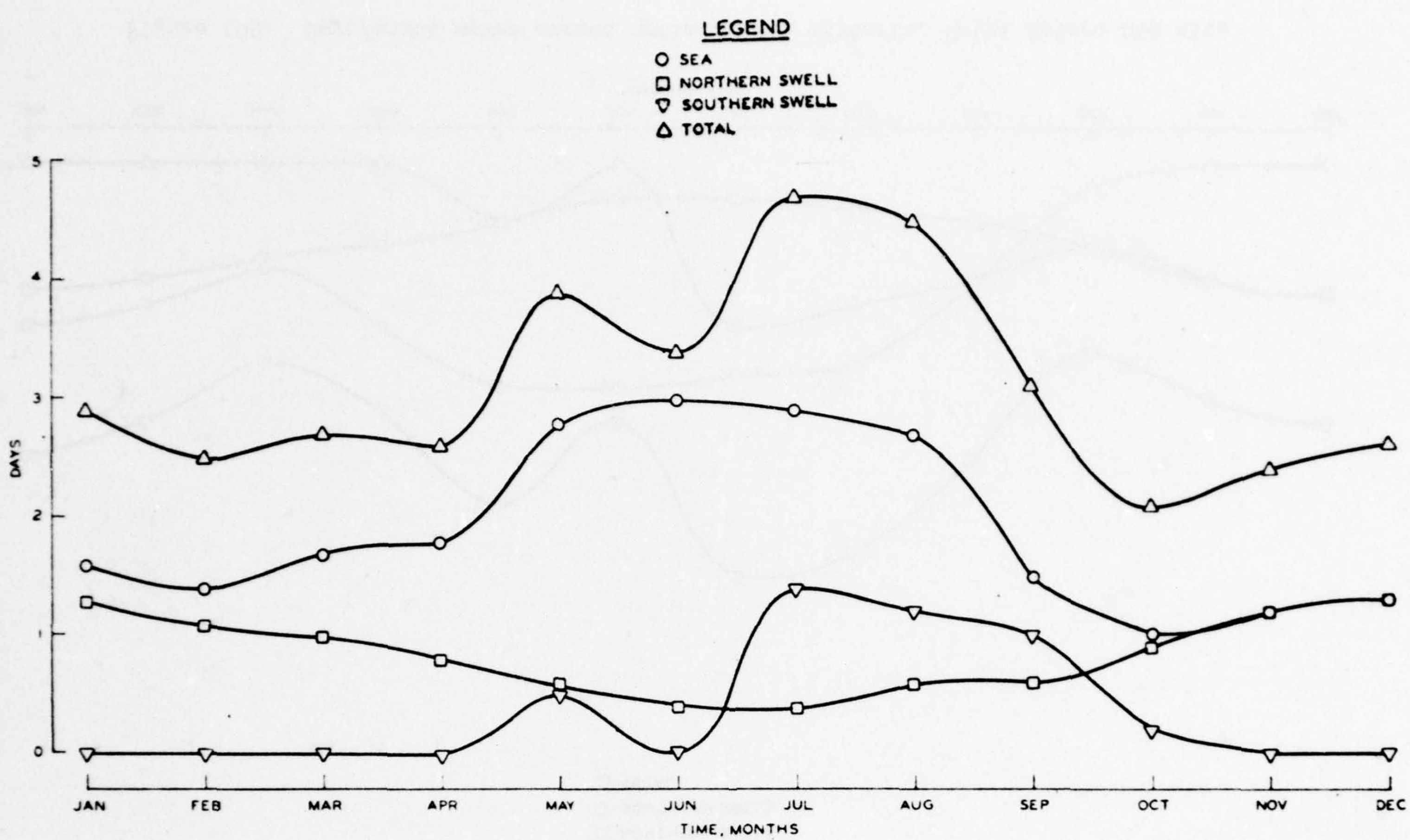

Figure 101. Days/month waves exceed optimization criteria, Point Buchon LNG site

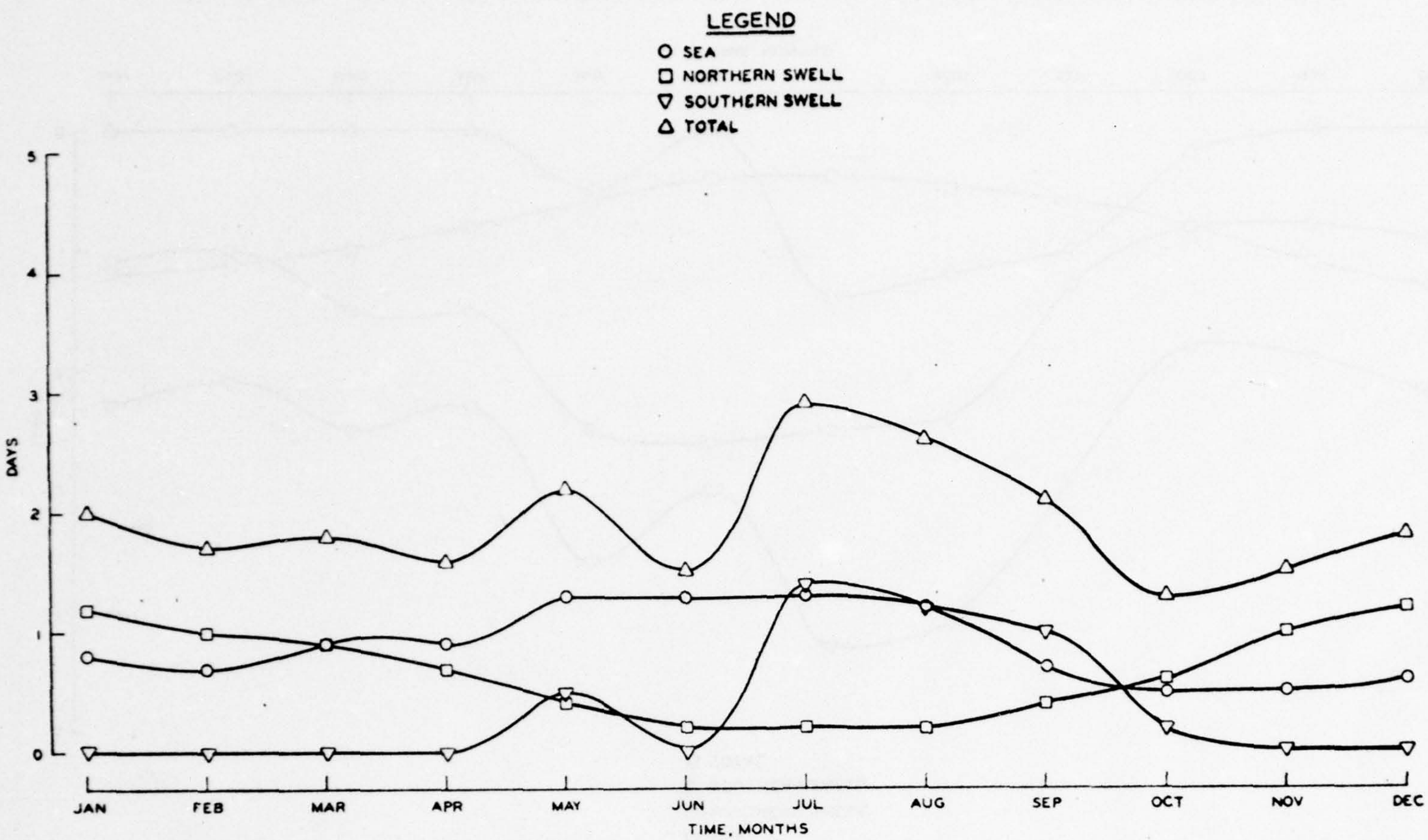

Figure 102. Days/month waves exceed optimization criteria, Oso Flaco Lagoon LNG site

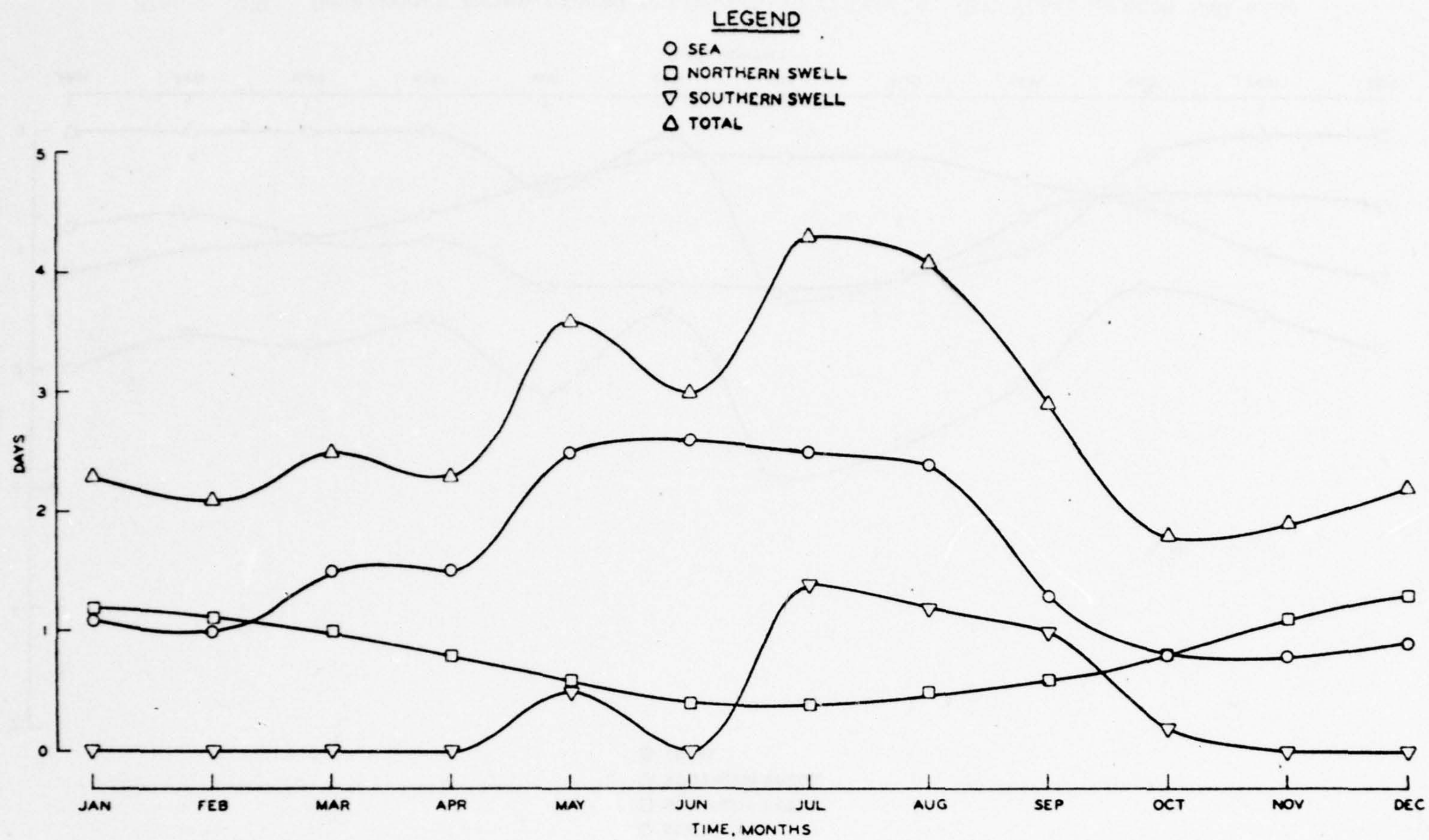

Figure 103. Days/month waves exceed optimization criteria, Guadalupe Dunes LNG site

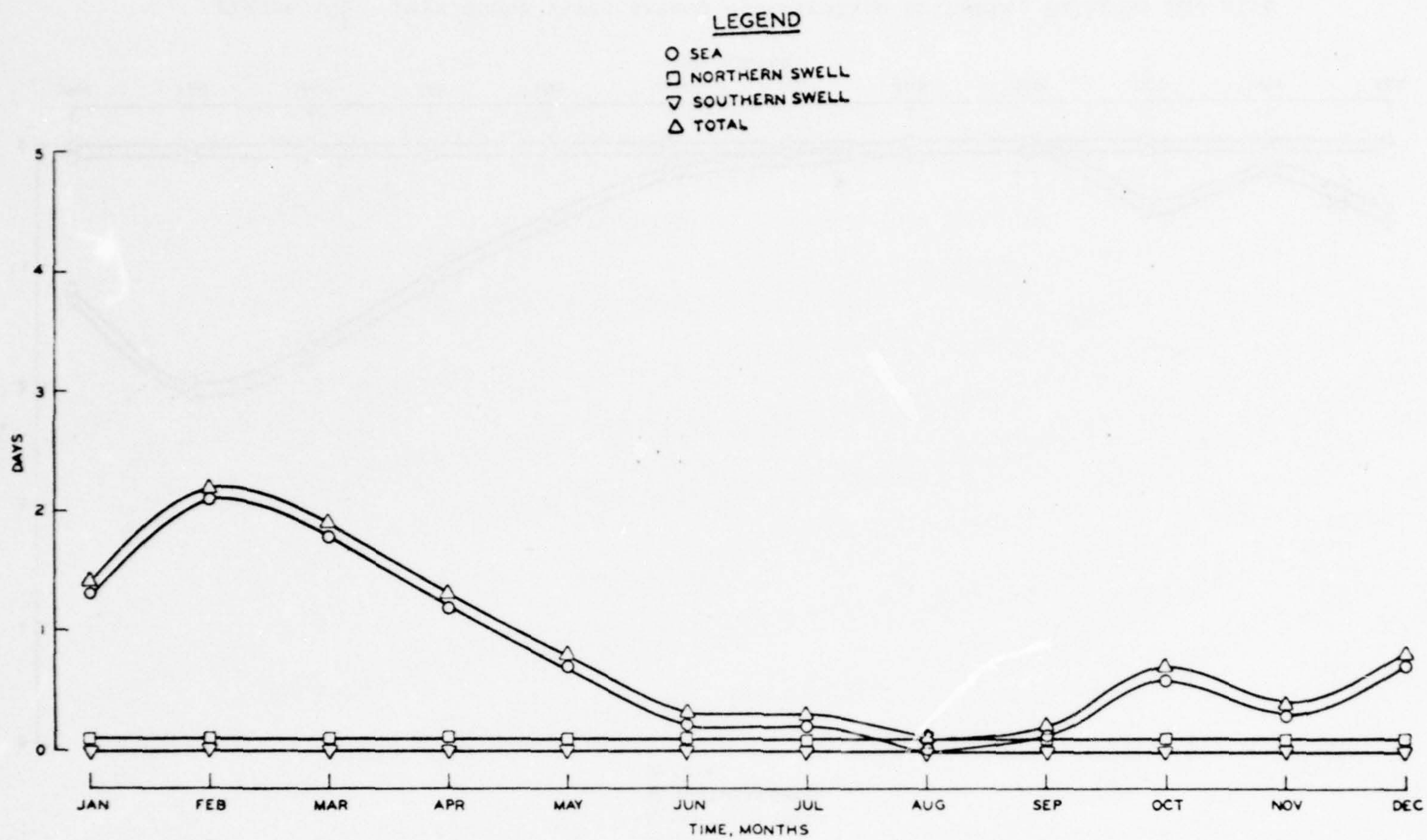

Figure 104. Days/month waves exceed optimization criteria, Point Conception LNG site

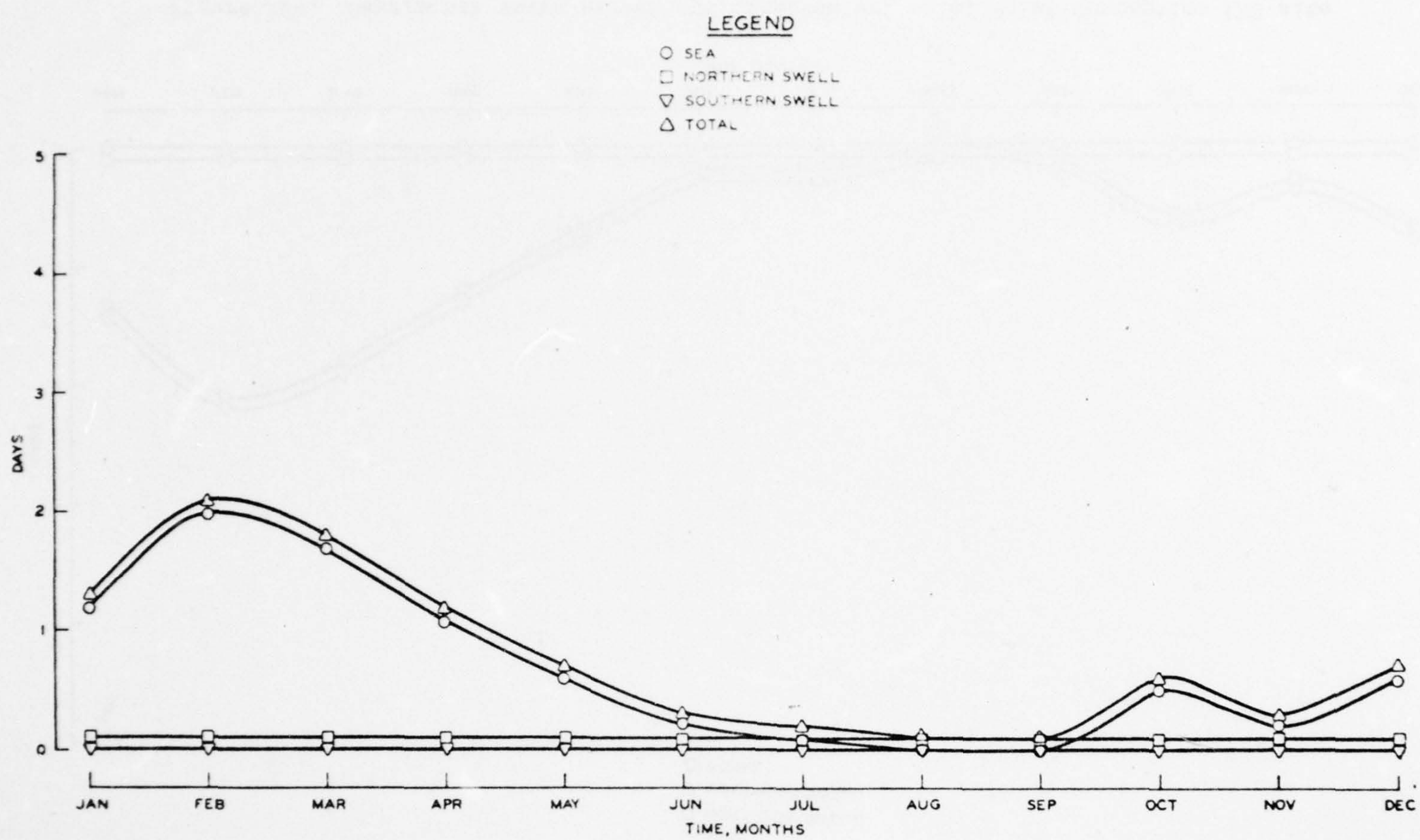

Figure 105. Days/month waves exceed optimization criteria, Tajiguas LNG site

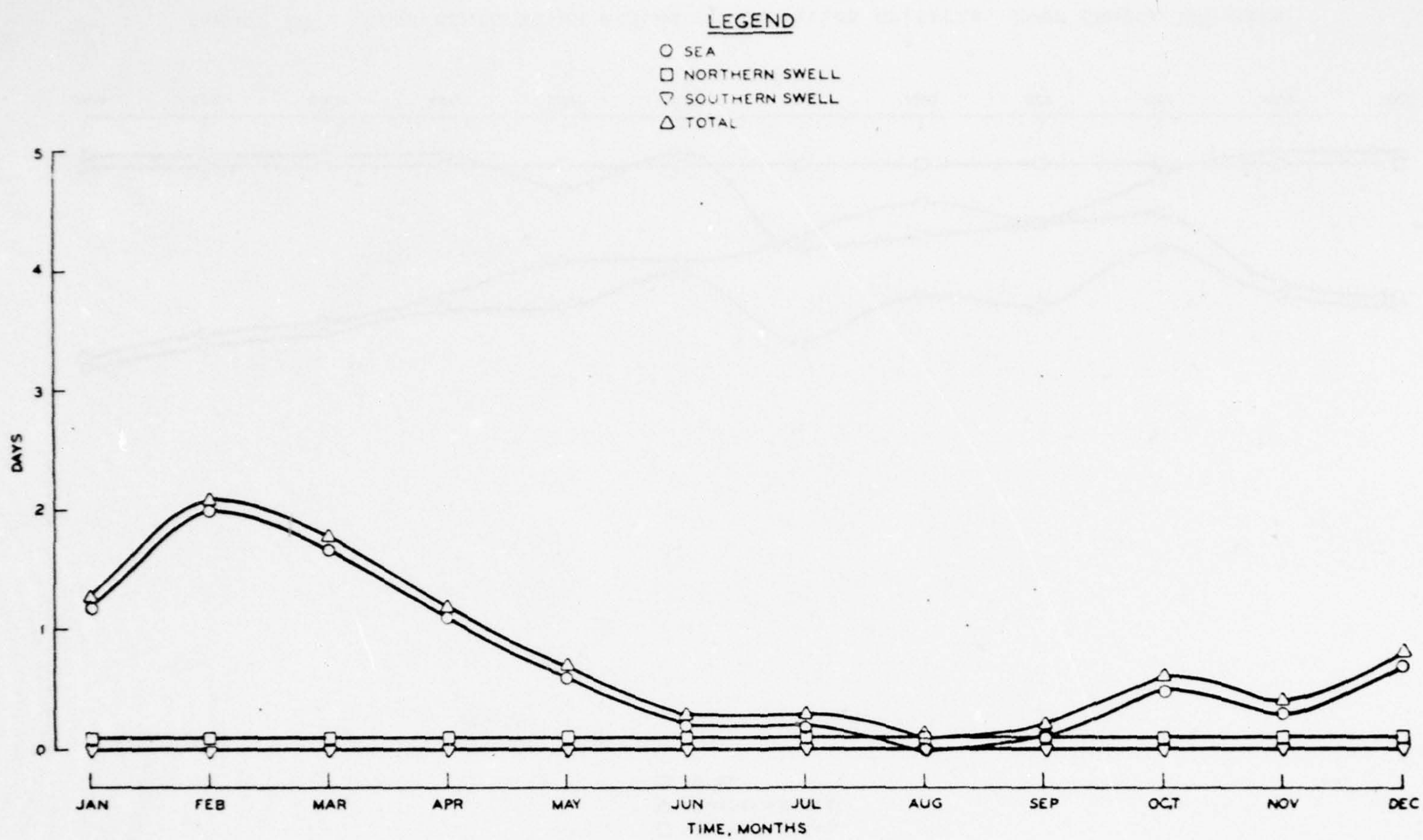

Figure 106. Days/month waves exceed optimization criteria, Dos Pueblos Ranch LNG site

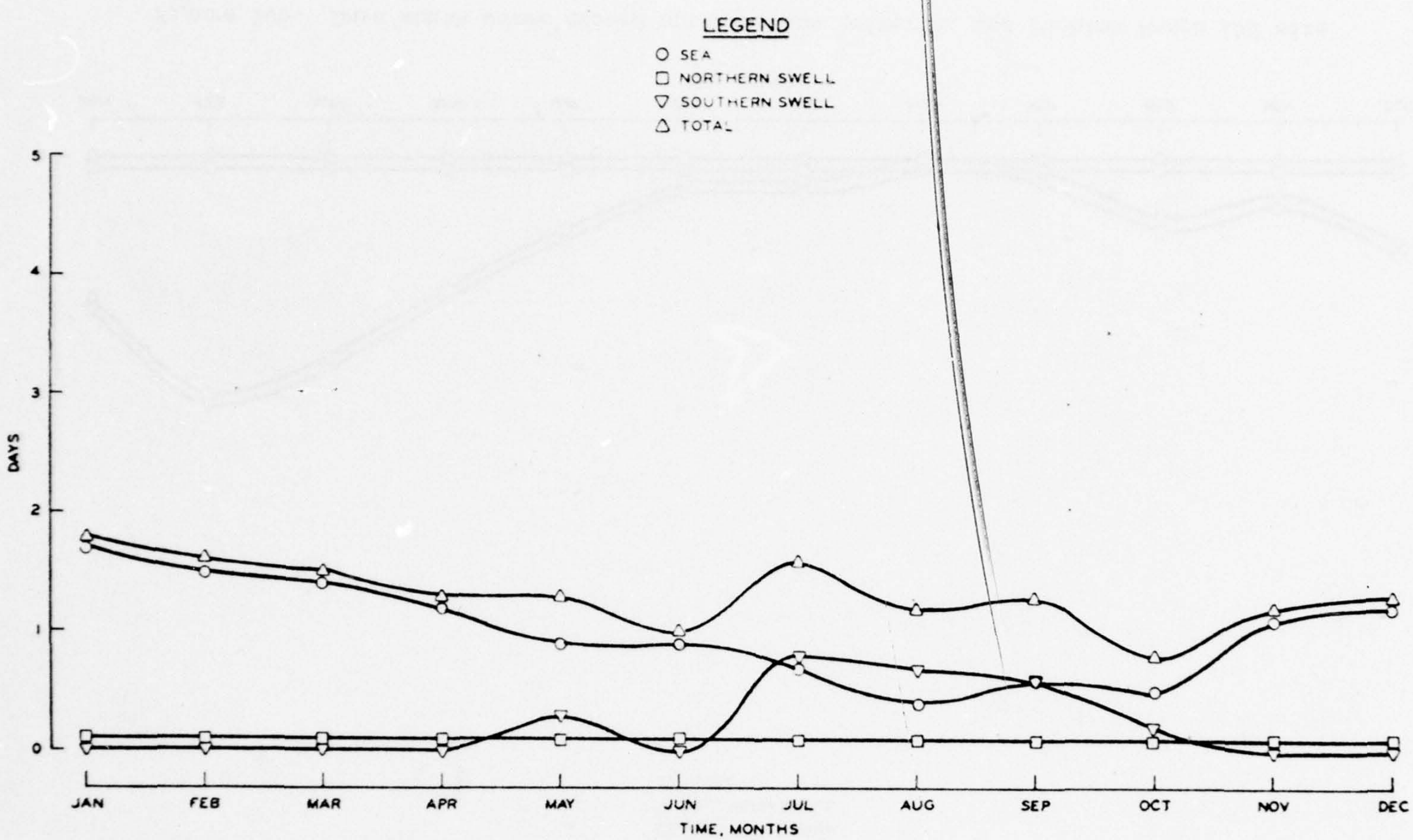

Figure 107. Days/month waves exceed optimization criteria, Deer Canyon LNG site

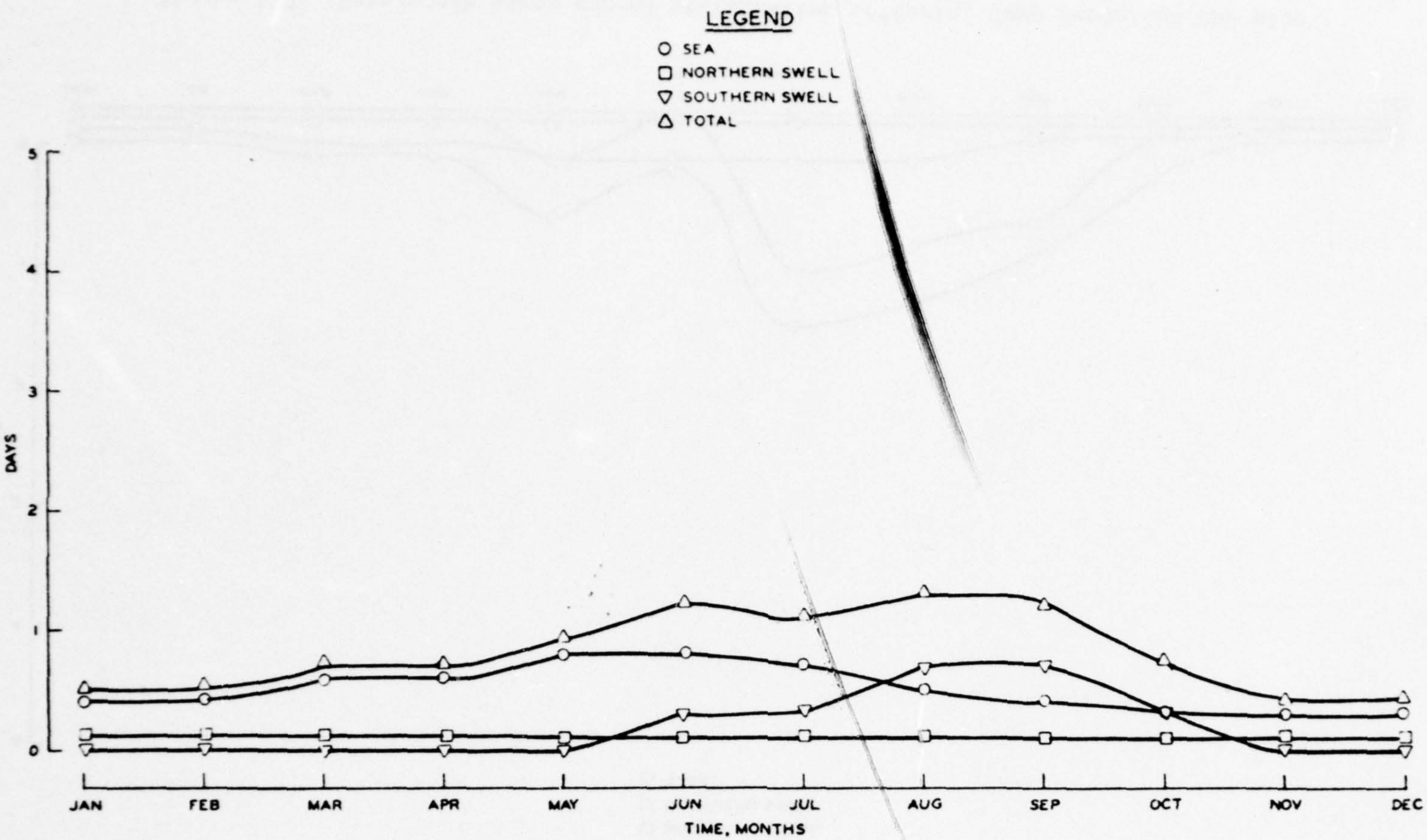

Figure 108. Days/month waves exceed optimization criteria, Redondo Beach LNG site

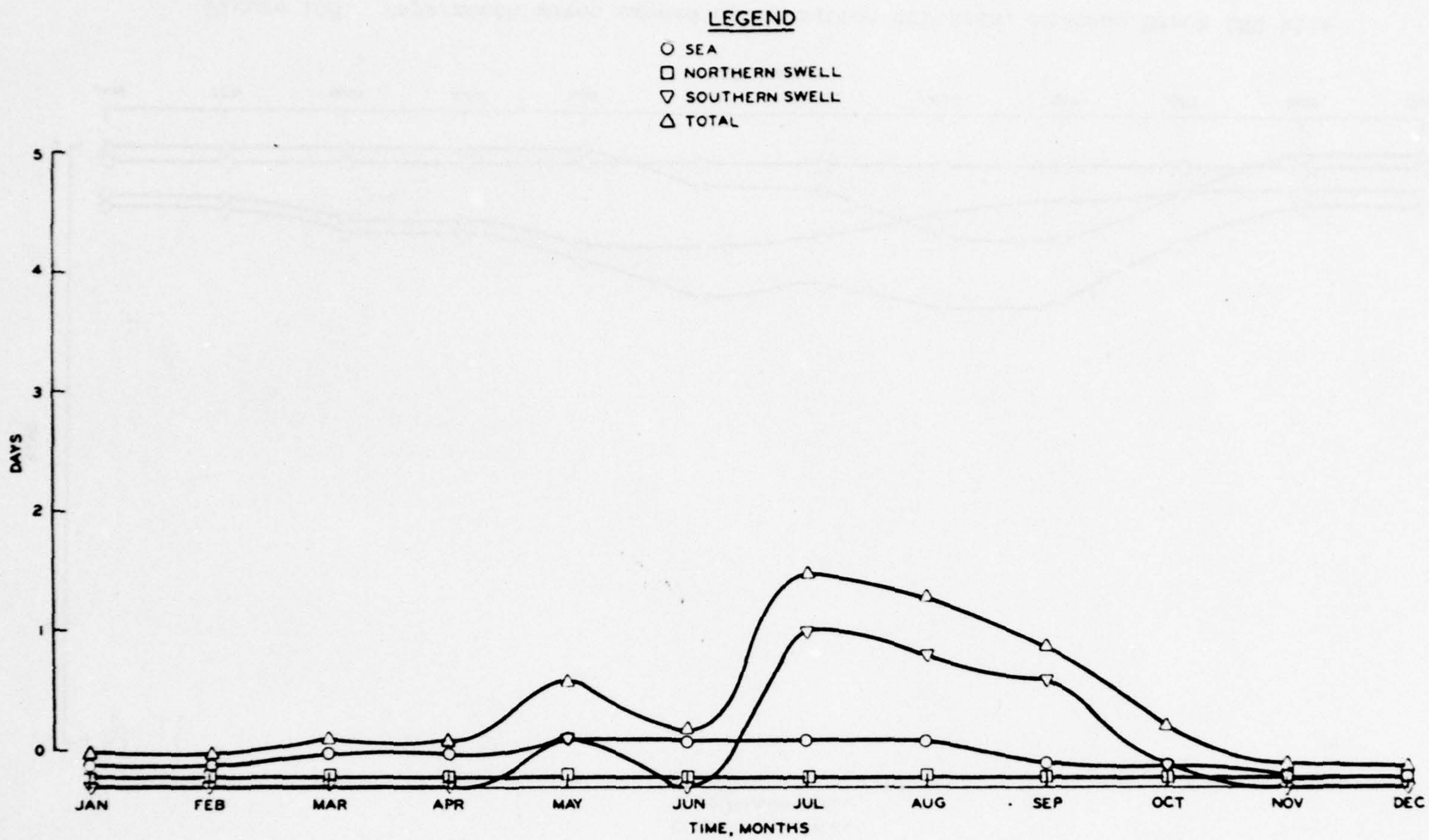

Figure 109. Days/month waves exceed optimization criteria, Camp Pendelton LNG site

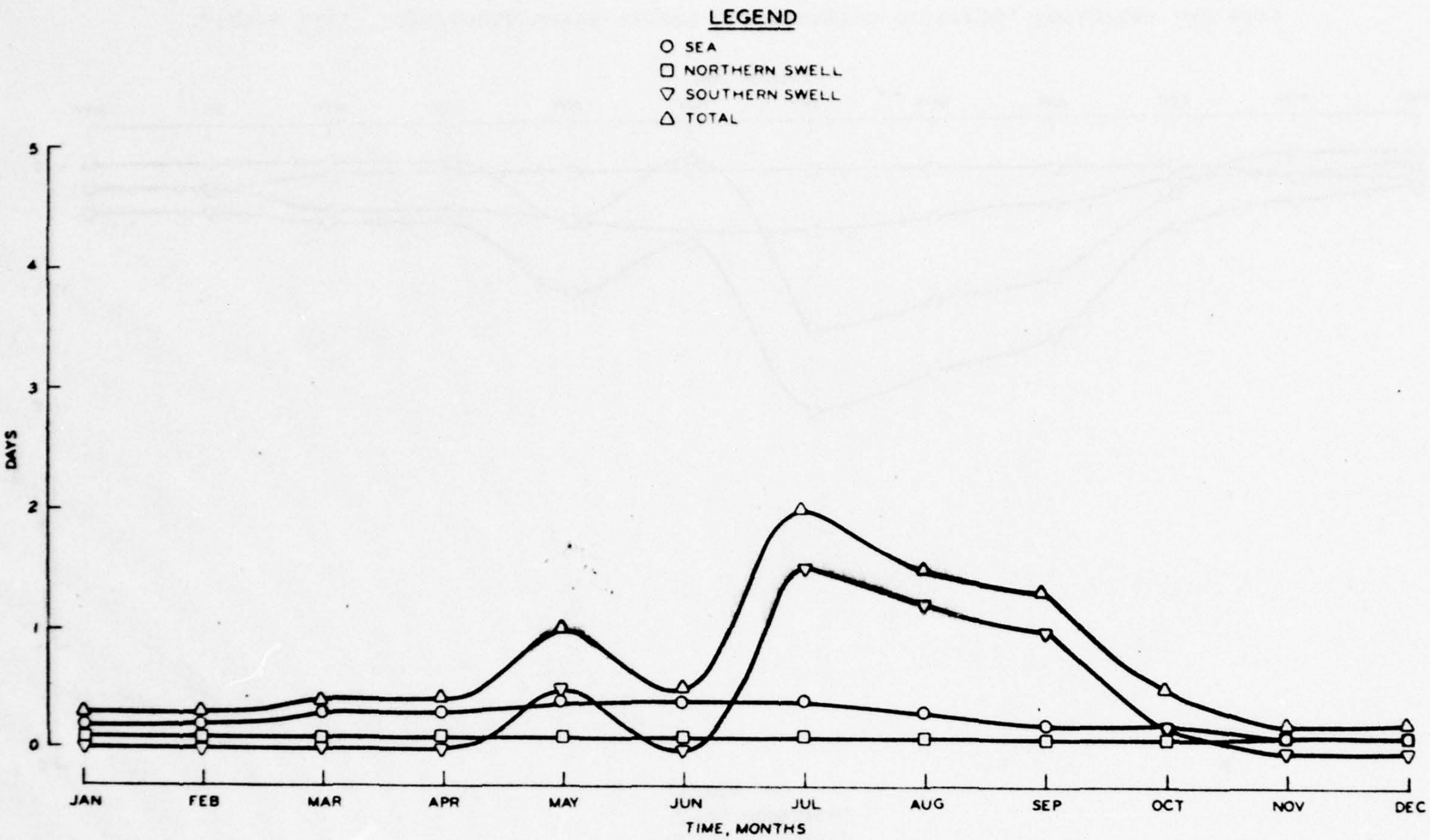

Figure 110. Days/month waves exceed optimization criteria, Oceanside LNG site

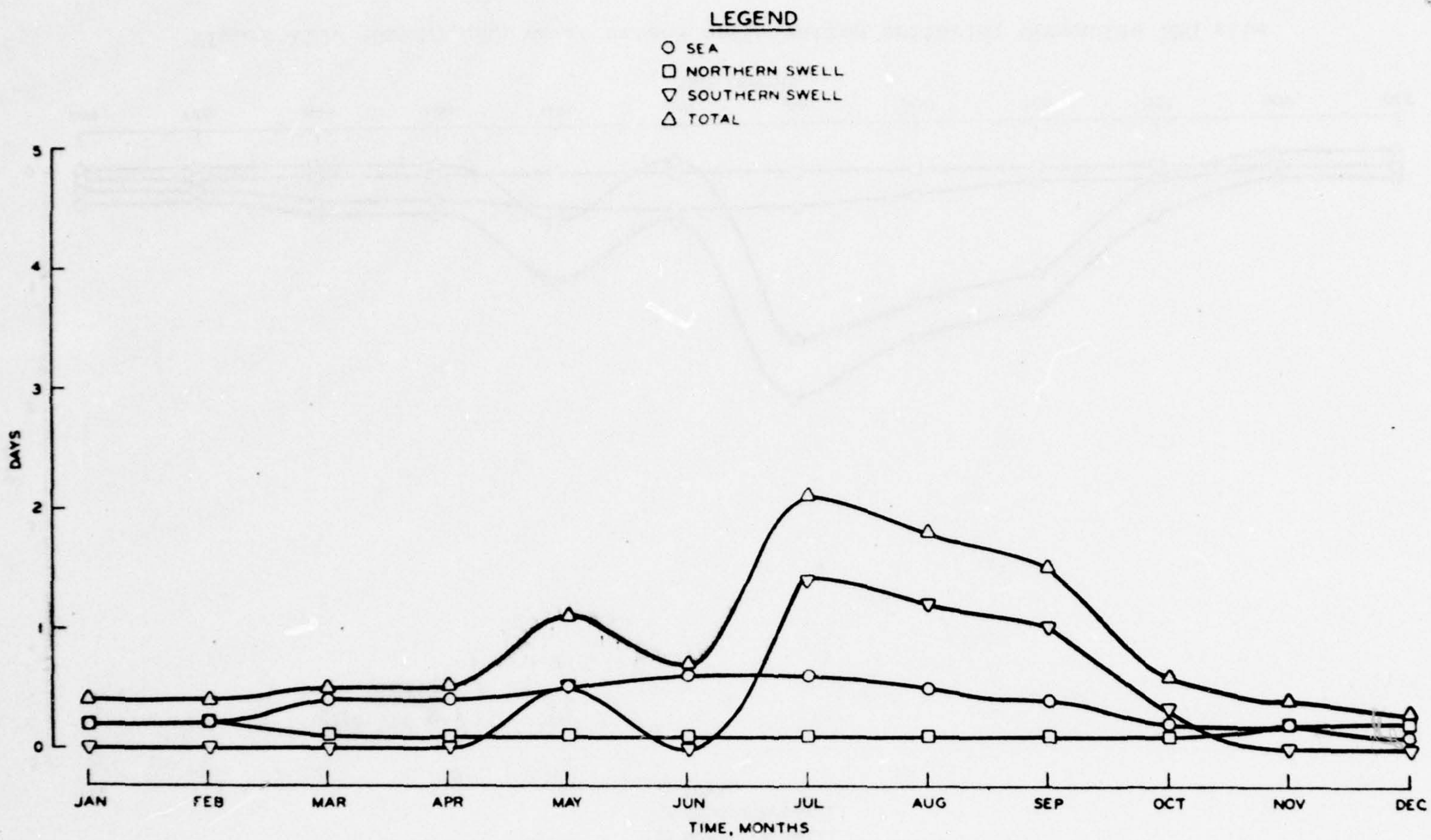

Figure 111. Days/month waves exceed optimization criteria, Encinitas LNG site

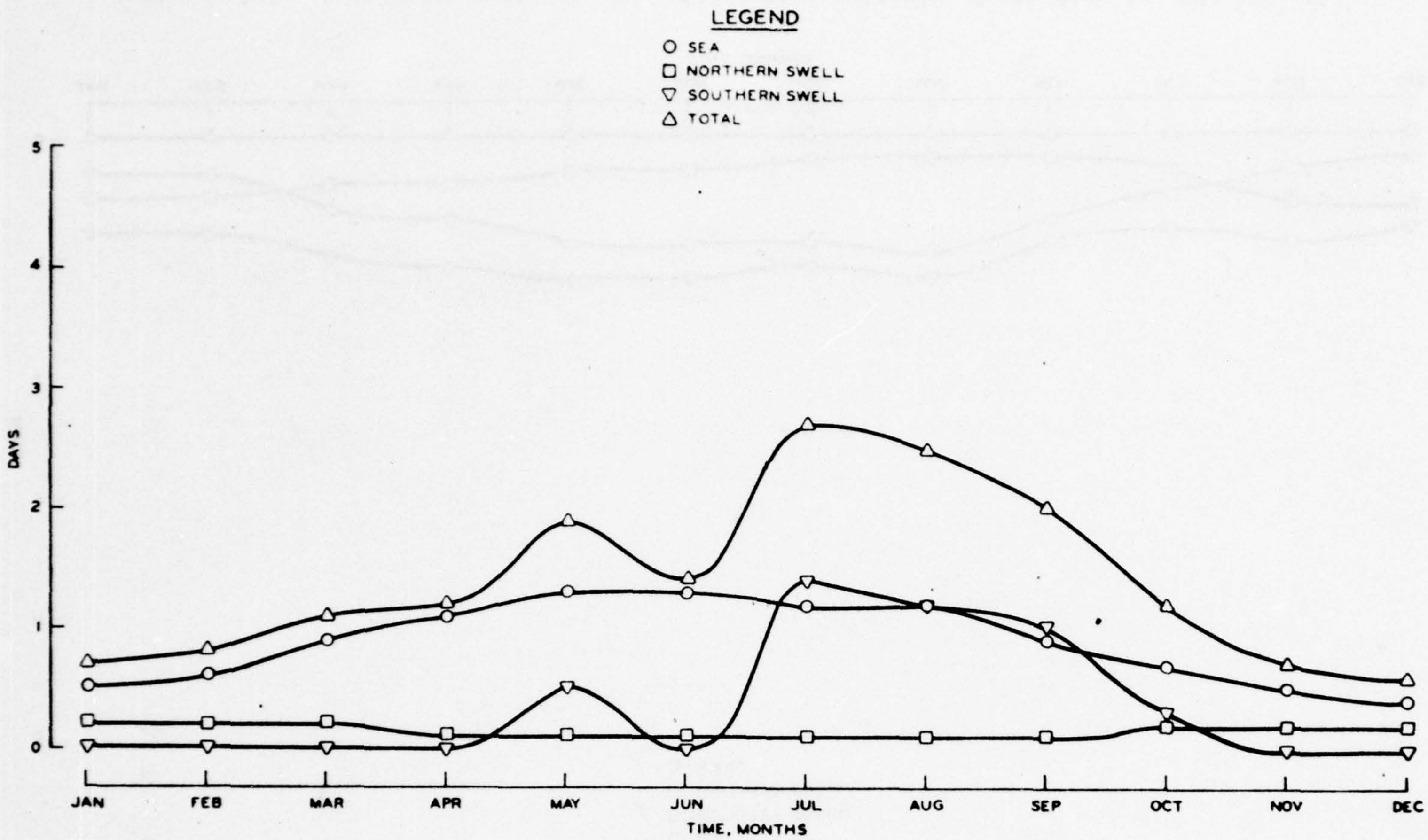

Figure 112. Days/month waves exceed optimization criteria, Mission Bay LNG site

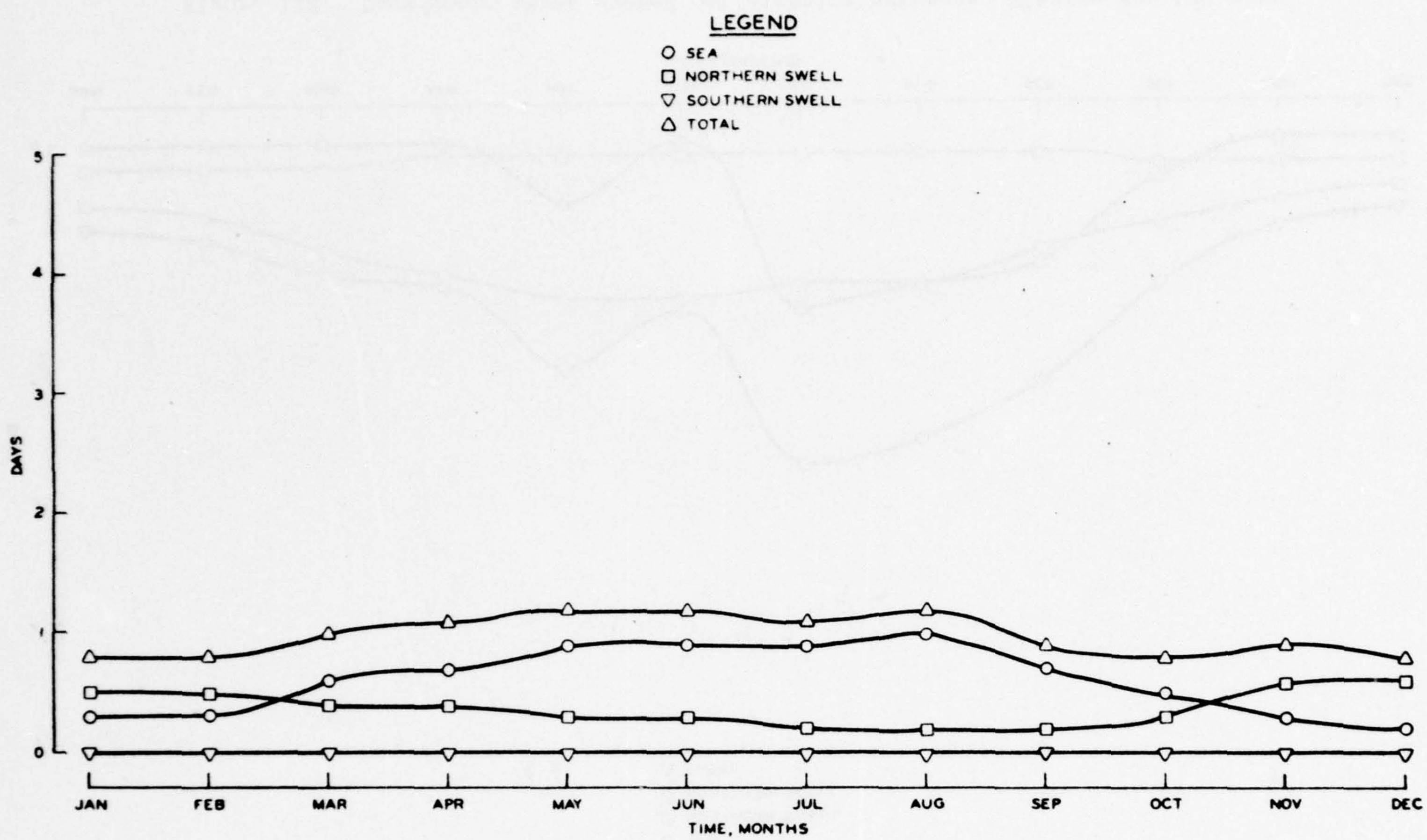

Figure 113. Days/month waves exceed optimization criteria, Santa Rosa Is. CCC LNG site

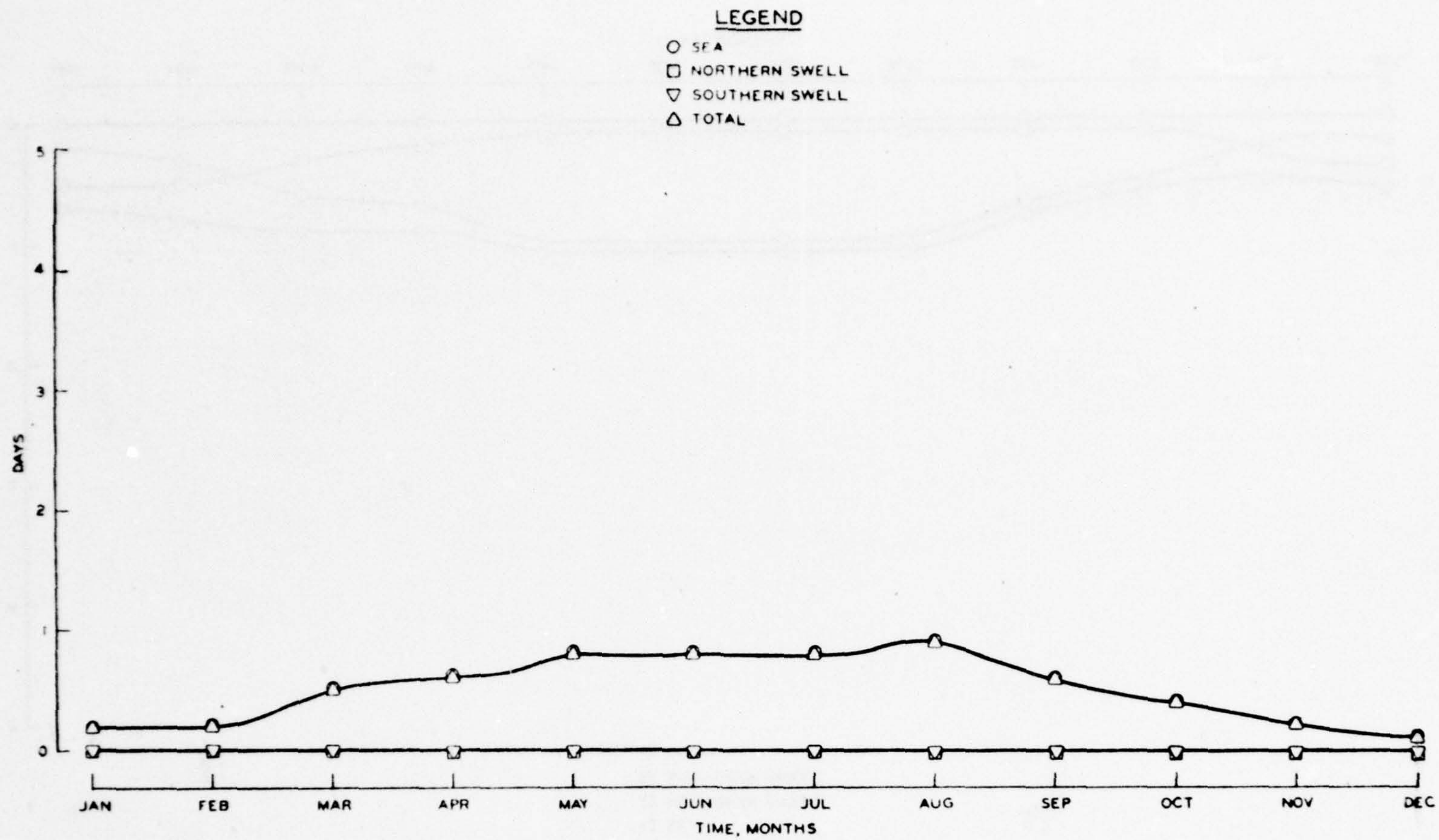

Figure 114. Days/month waves exceed optimization criteria, Santa Rosa Is. WES LNG site

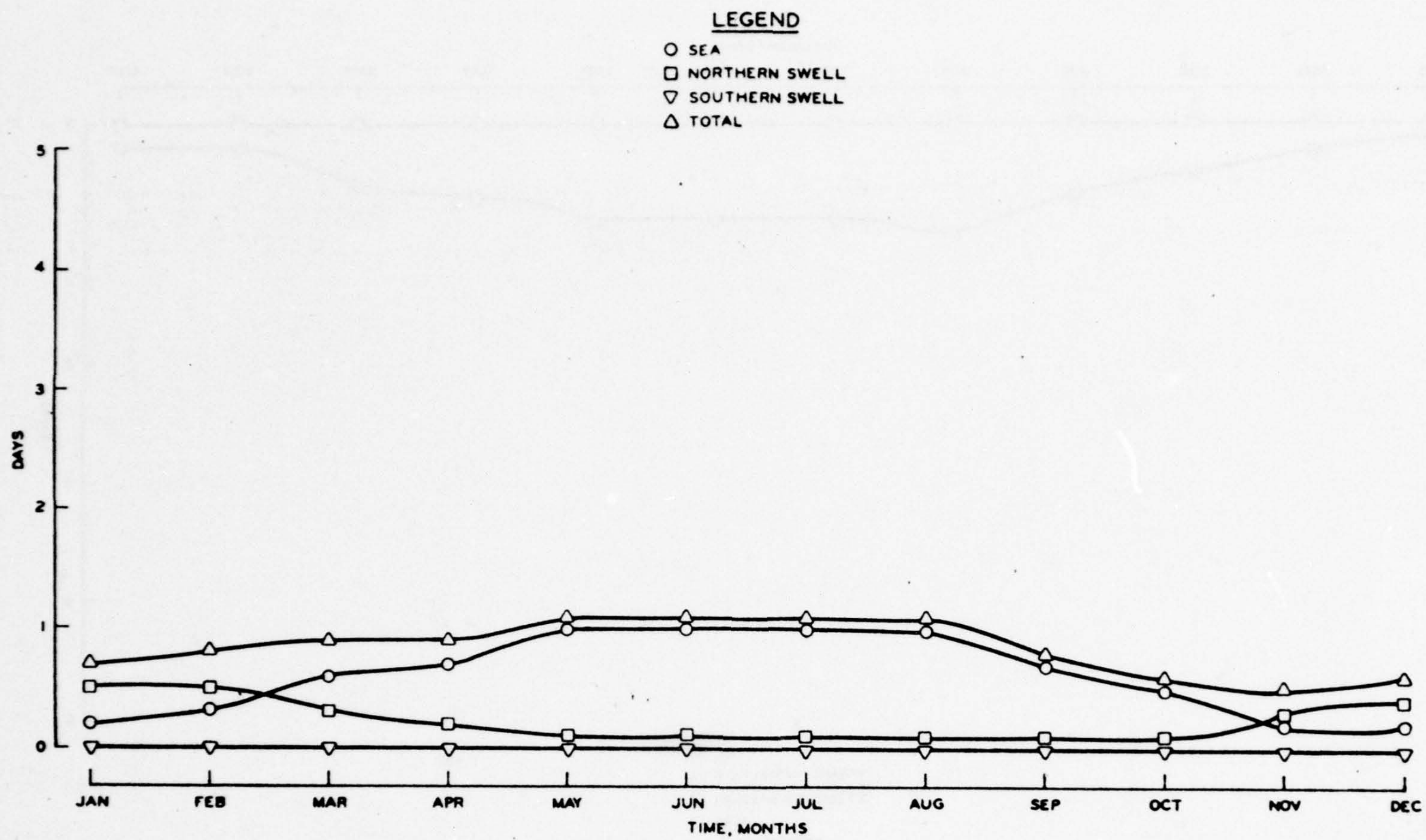

Figure 115. Days/month waves exceed optimization criteria, Santa Cruz Is. N. LNG site

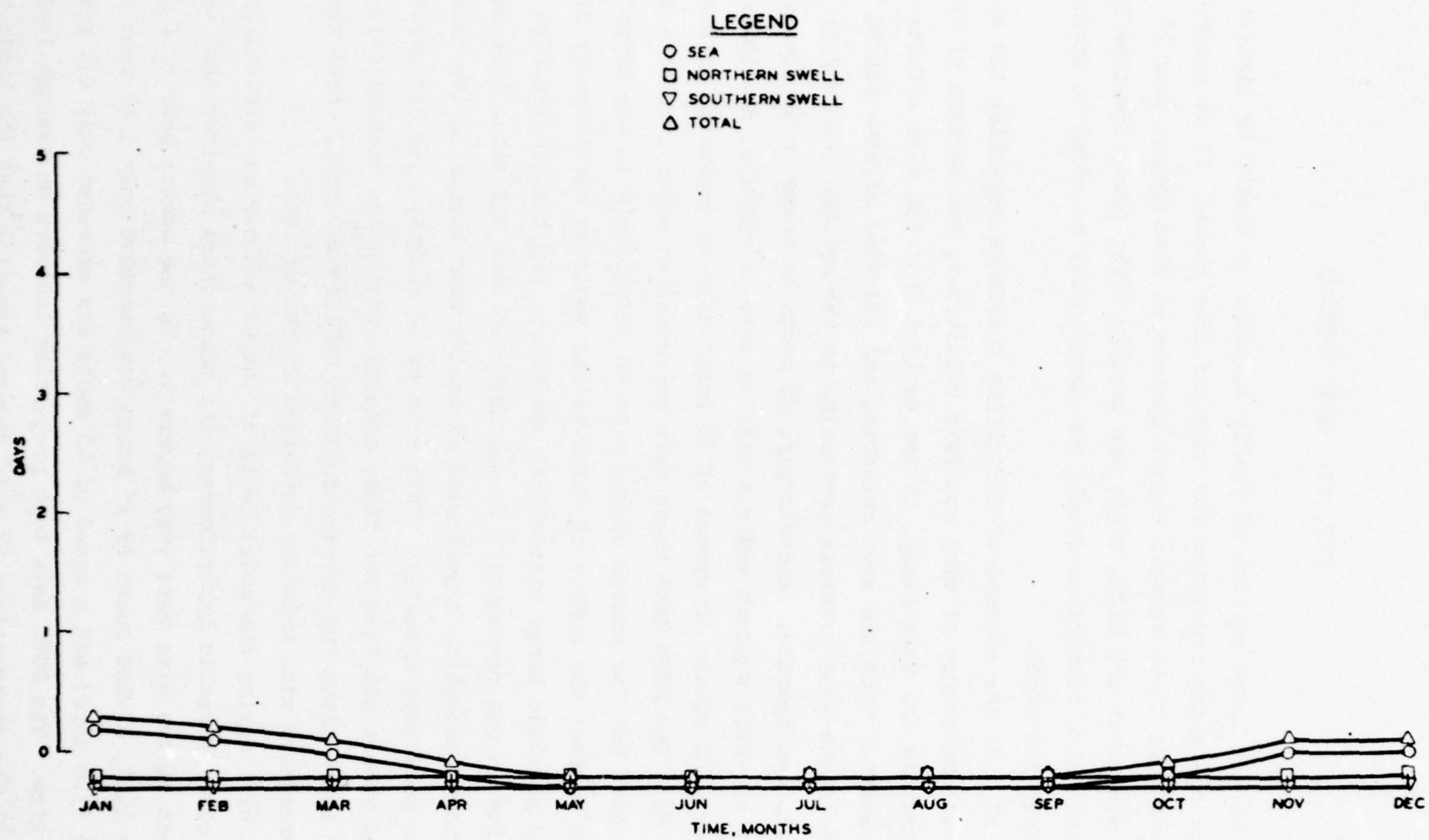

Figure 116. Days/month waves exceed optimization criteria, Santa Cruz Is. E. LNG site

PART VI: WIND EFFECTS

66. A large portion of yearly downtime is caused by limitations on the operating condition for tugs and line boats. It is generally assumed that these vessels cannot operate at wind speeds over 25 knots. When sea waves are high, winds are usually high; thus, downtime because of large wave conditions should not necessarily be added to downtime due to excessive winds.

67. In the absence of definitive knowledge regarding the simultaneous occurrence of wind and wave conditions, and because of the time constraints for this study, it was decided that the wave effects should be presented with the wave criteria, and the wind effects should be related to the wind criteria pertaining to the maximum velocity in which vessels can operate. Accordingly, 25 knots is taken to be the upper limit at which support vessels will be able to operate, and those days having wind speeds in excess of 25 knots will be evaluated as downtime.

68. The SSMO data tapes were processed at seven locations along the coast but far enough offshore to be effectively in the shipping lanes so that the number of observations would be sufficiently high so as to preclude large statistical variances, and thus insure high reliability in the estimates. It was observed that all sites located north of Point Conception experienced excessive wind speeds on the order of 40 or more days annually. This contrasted sharply with the greatly reduced values obtained for those stations inside the channel islands and near shore along the extreme southern California coast. Here the days of excessive wind velocity decreased to ten or less.

69. During the model tests of the Oxnard marine terminal performed by Delft Hydraulic Laboratories, the researchers observed that the wind speeds at the site were very moderate. In the severe year of July 1961-June 1962, a wind speed of 25 knots was exceeded only 1 percent of the time (3.6 days) and a speed of 40 knots was exceeded only 0.1 percent of the time. The SSMO data tape processing includes an average (weighted) of all the observations in a 1° square, assuming that the particular

point of interest is positioned at the center of this square. This accounts for the fact that the SSMO data indicates wind values in excess of 25 knots occurring 1.6 percent of the time near the Oxnard vicinity, as compared with 1 percent from the Delft report, because the values being processed by the SSMO procedure include some observations seaward from the point of interest. However, the SSMO data for locations south of Los Angeles in the Gulf of Santa Catalina show considerably lower values, approaching 1 percent or less of the time in excess of the 25 knot criteria.

70. Delft Hydraulic Laboratories[8] also investigated wind speed effects near the proposed Point Conception LNG terminal site (on the southern coast of California just east of Point Conception). Here it was found that in most directions wind speeds of 25 knots correspond with the wind wave (sea) heights less than 4-7 ft and relative short periods. This wave condition coincided fairly well with the condition that is generally accepted as a limitation for the operation of line boats. For both tug and line boats, the same 25 knot criterion was taken throughout and no consideration given to the extra power that must be consumed for overcoming the additional pressure forces exerted by high winds on the projected area of the vessels.

71. Oceanographic Services, Inc.[9] have also analyzed wind records near Point Conception, and postulated wind speeds in excess of 25 knots occurred approximately 3.4 percent of the time (up to 12 days/year). Only two years of record were analyzed in this study, and this region is near the open exposure of the Pacific ocean; hence the results are both plausible and probable.

72. Wind values appear to occur as a smoothly varying function from one location to another, so the results of studies by different researchers of a particular region do not seem to vary over such a large range of values as do wave climate determinations. This is probably due in part to the large degree of subjectivity that goes into a hindcast study, the particular years of record being analyzed, and the method in which the wave model is formulated.

73. The specific locations of the sites for which SSMO wind data were processed are shown in Figure 117. Here it will be observed that four stations were selected on the western side of the state to monitor the open coastal wind climate, and three stations were selected south of Point Conception inside the channel islands to reveal the wind effects on sites located both on the southern mainland and on the islands. Because of the smooth variations expected to occur in the wind values over long periods of time, the specific values estimated to occur annually at a particular LNG terminal site were obtained by fitting a smooth curve through the computed points.

74. Histograms of the number of days the winds exceeded specified values were prepared for each of the seven sites where the SSMO data tapes had been processed. This results in a visual display in Figures 118 through 124 where the sensitivity of the downtime to the criteria expressed for wind velocity can be observed. As noted by the Delft researchers, if the limiting criteria for wind can be increased to 30 knots from 25 knots, the downtime caused by these winds will be reduced 50 percent or more in all cases.

75. The wind values which exceeded 25 knots in the annual consideration were broken down monthly so as to provide an indication of the expected seasonal variation. These monthly evaluations are presented in Figures 125 through 131, where it is observed that the distribution over the year is fairly uniform, never exceeding 10 days per month (on the average) for any of the sites chosen. The very low values for southern California are again emphasized.

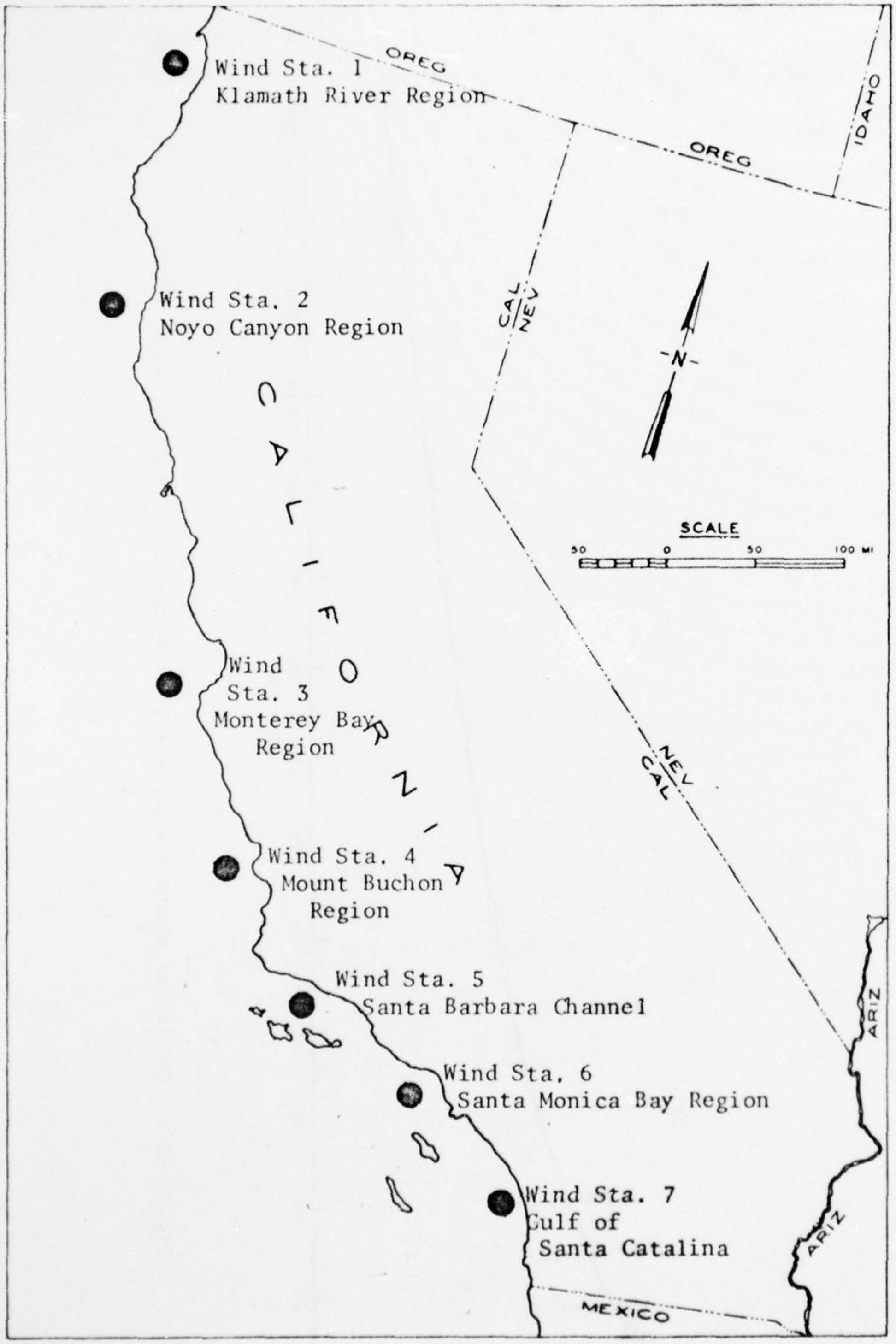

Figure 117. Wind stations developed from SSMO observations

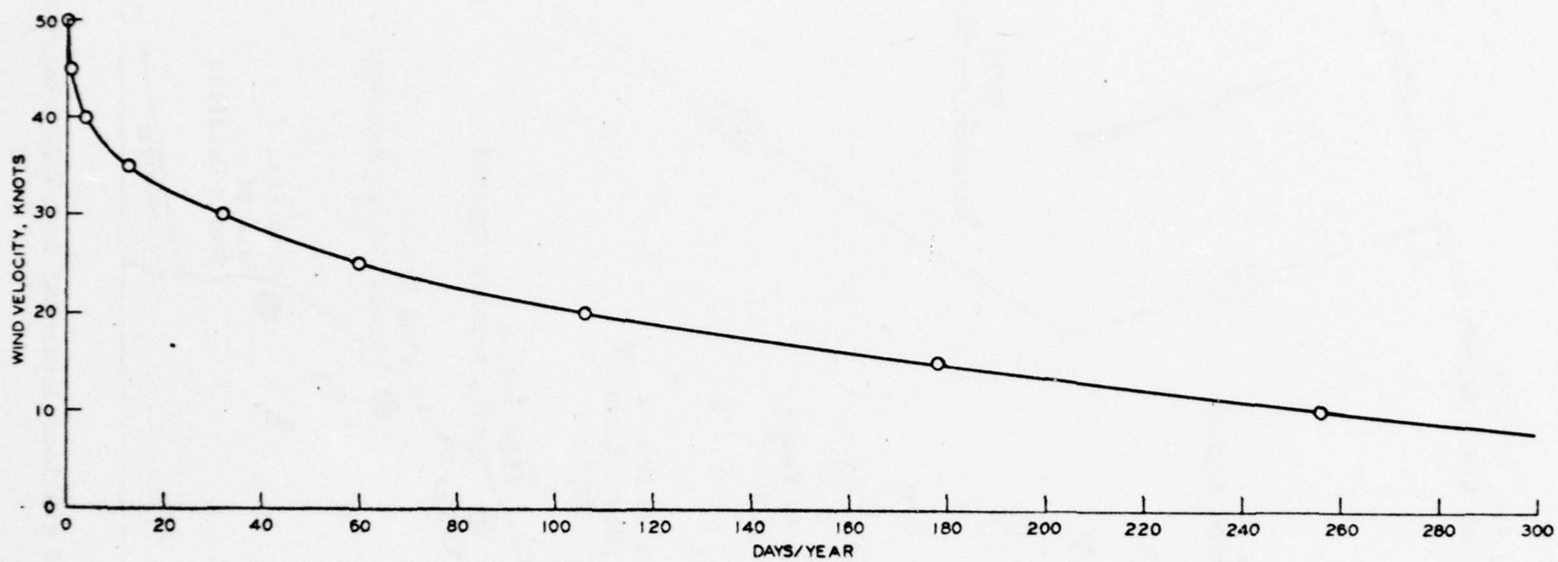

Figure 118. Days/year winds exceed specific velocities (knots), wind station 1

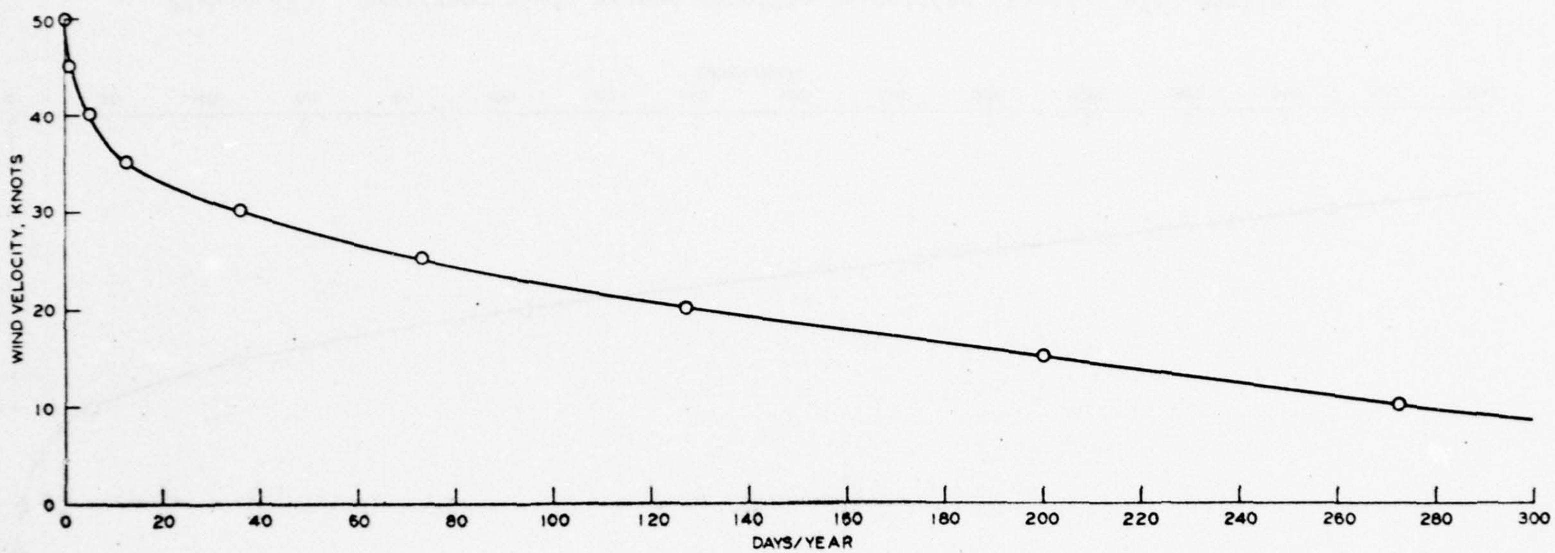

Figure 119. Days/year winds exceed specific velocities (knots), wind station 2

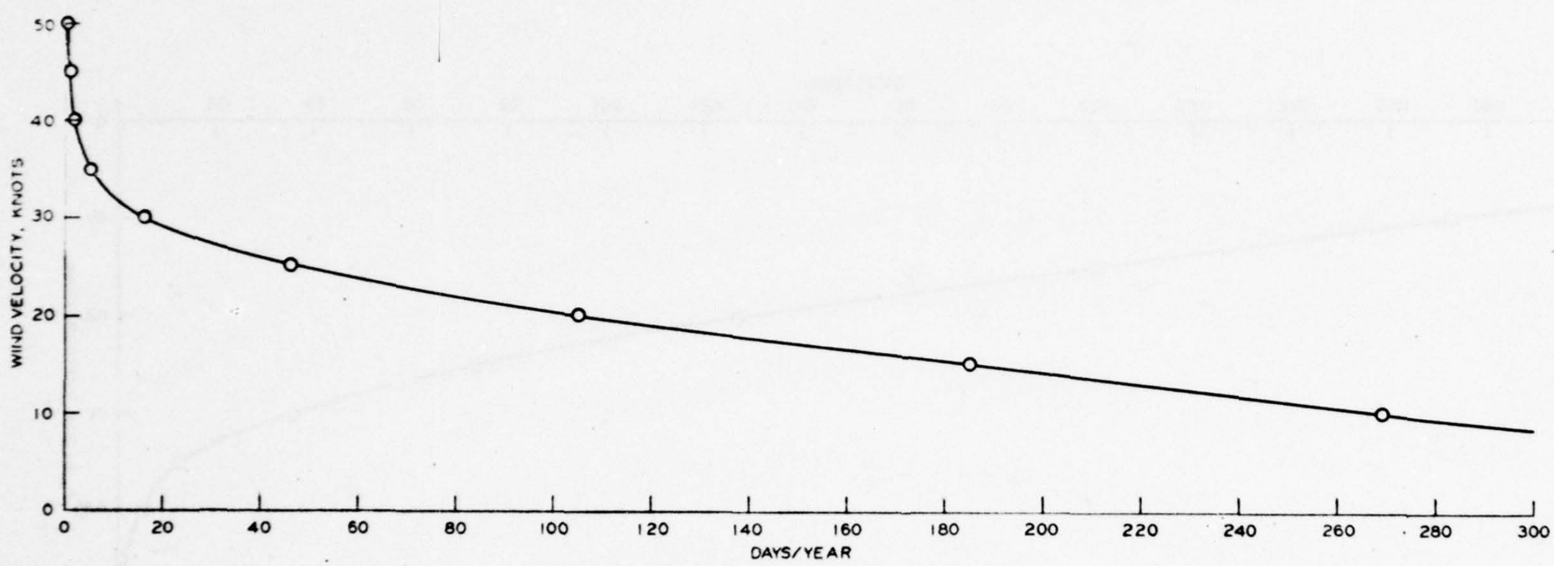

Figure 120. Days/year winds exceed specific velocities (knots), wind station 3

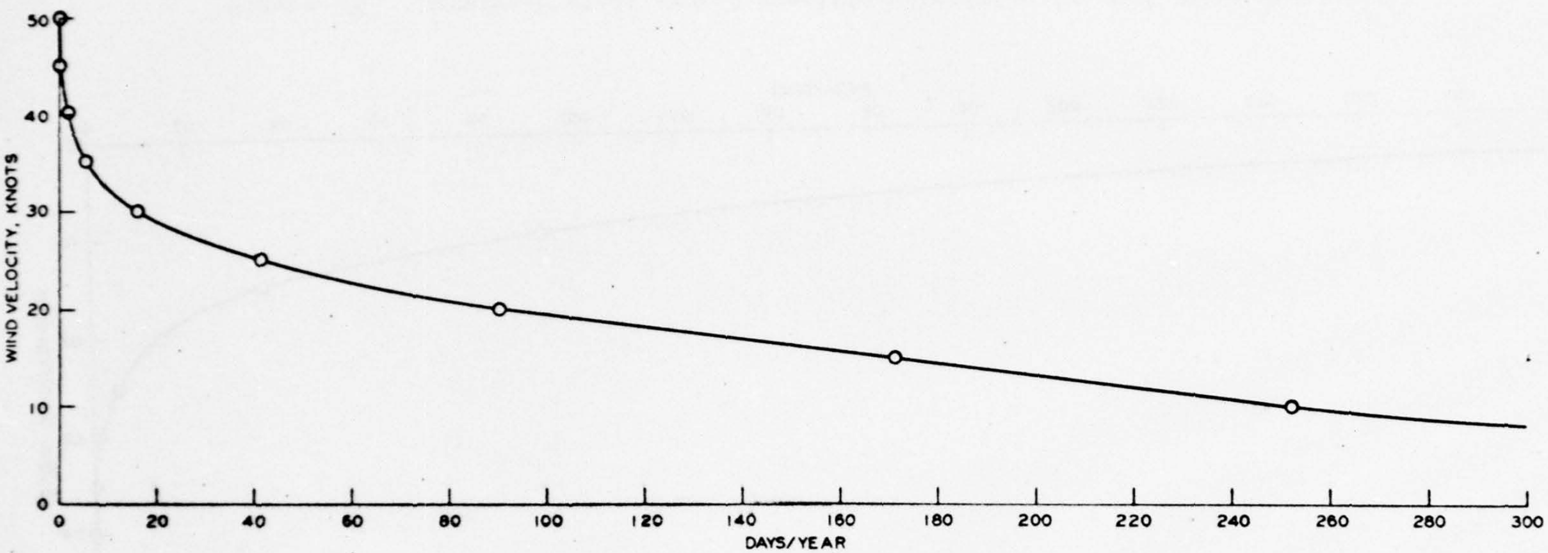

Figure 121. Days/year winds exceed specific velocities (knots), wind station 4

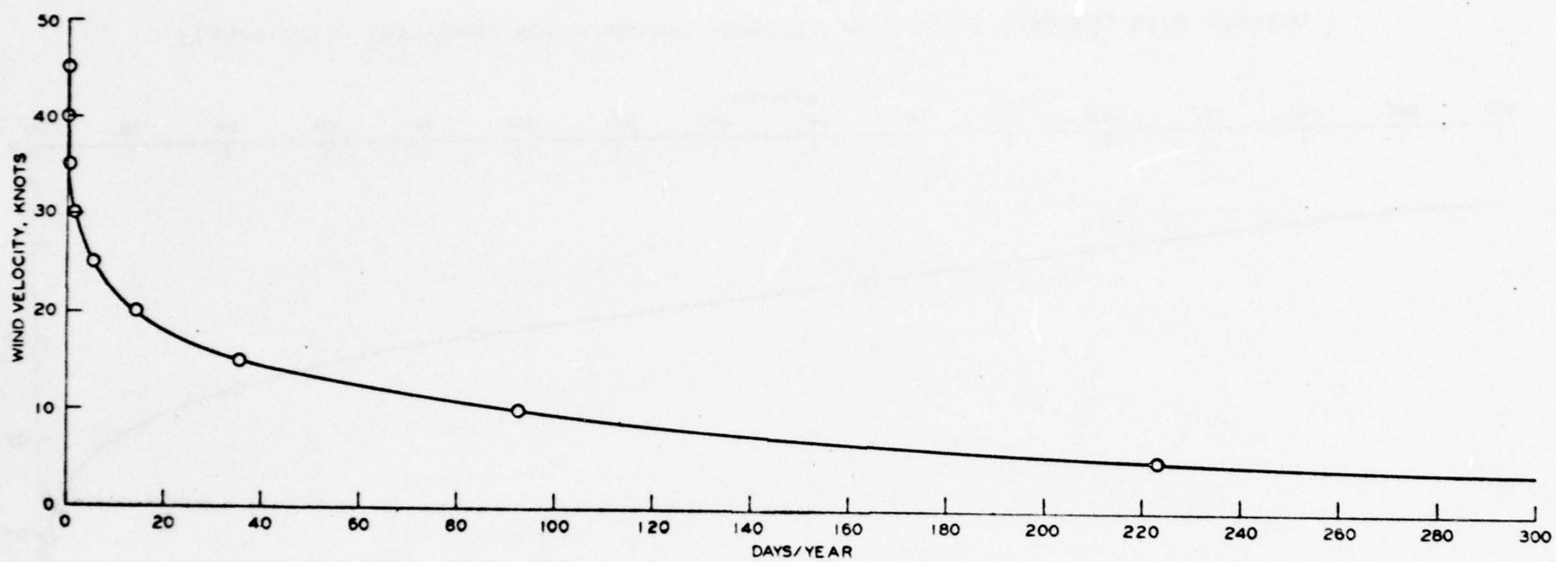

Figure 122. Days/year winds exceed specific velocities (knots), wind station 5

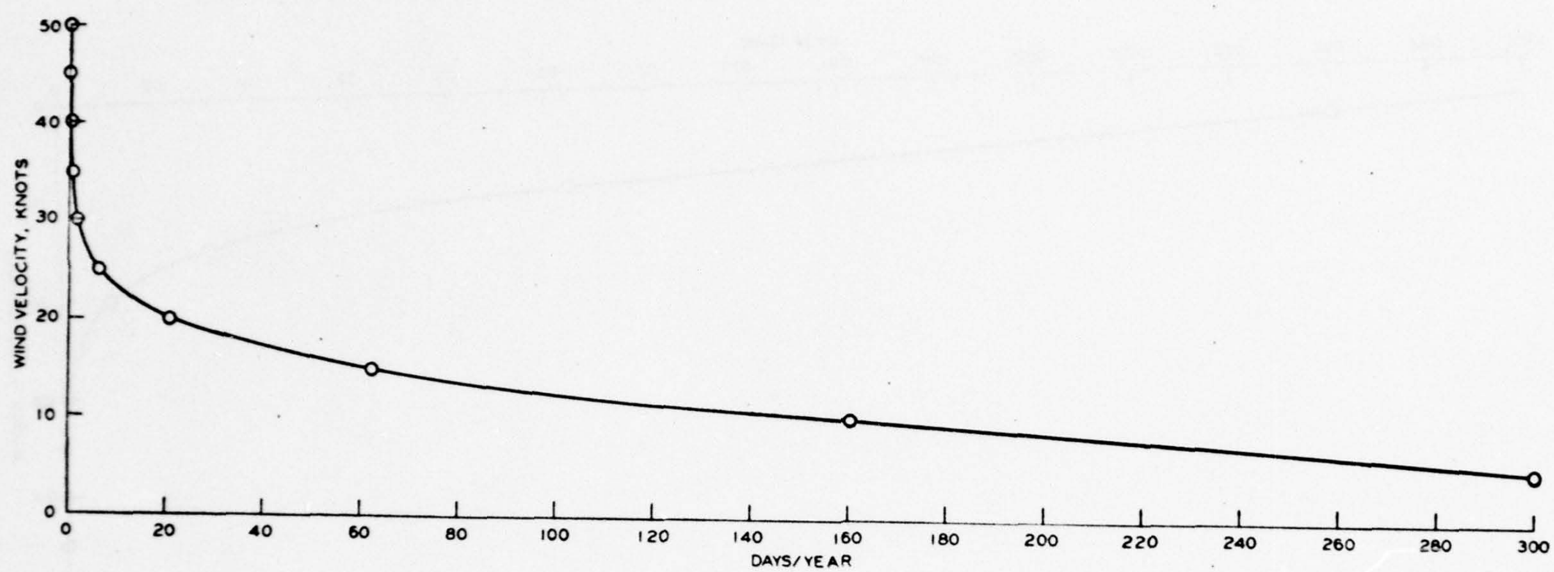

Figure 123. Days/year winds exceed specific velocities (knots), wind station 6

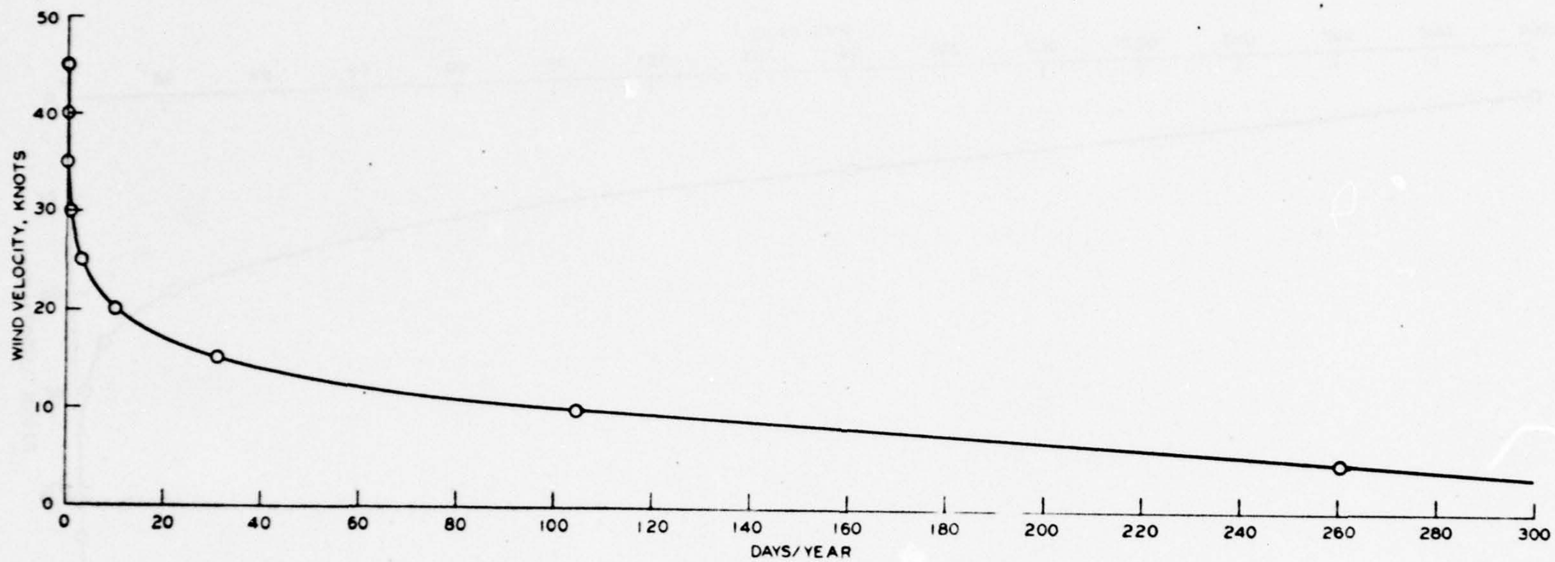

Figure 124. Days/year winds exceed specific velocities (knots), wind station 7

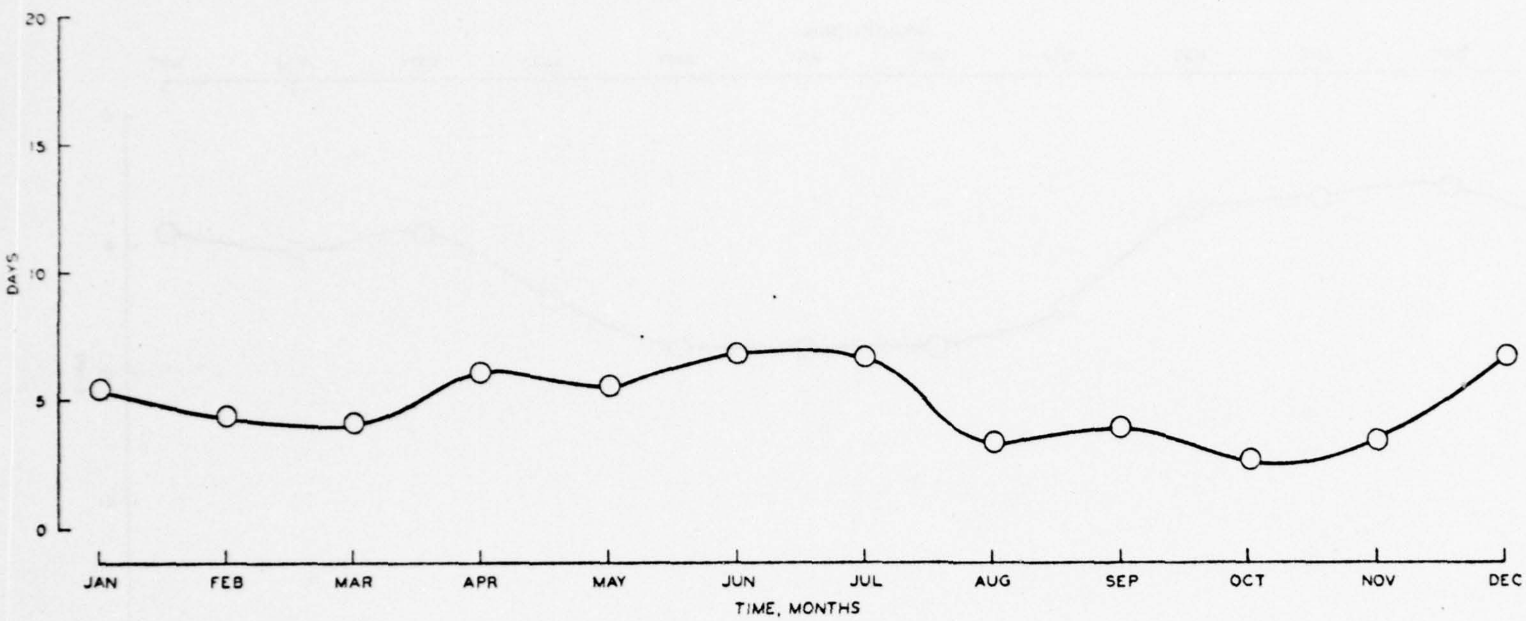

Figure 125. Days/month winds exceed 25-knot velocity, wind station 1

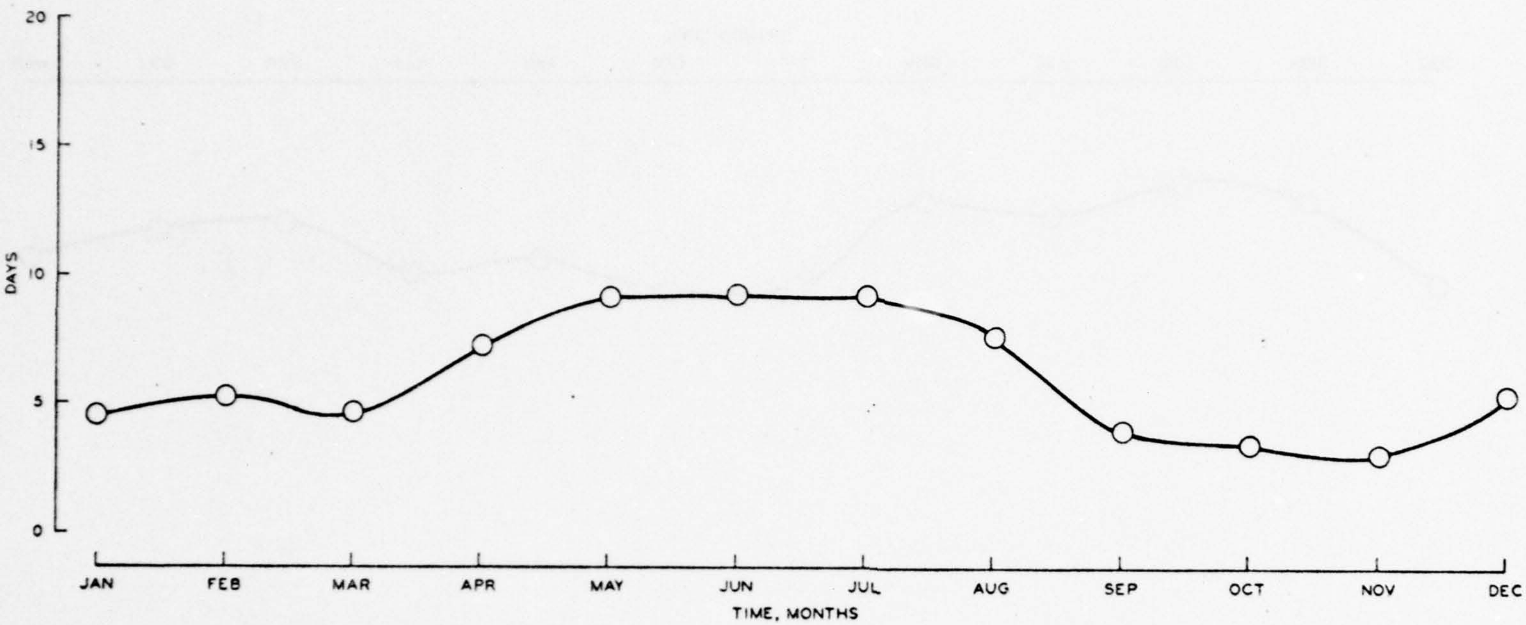

Figure 126. Days/month winds exceed 25-knot velocity, wind station 2

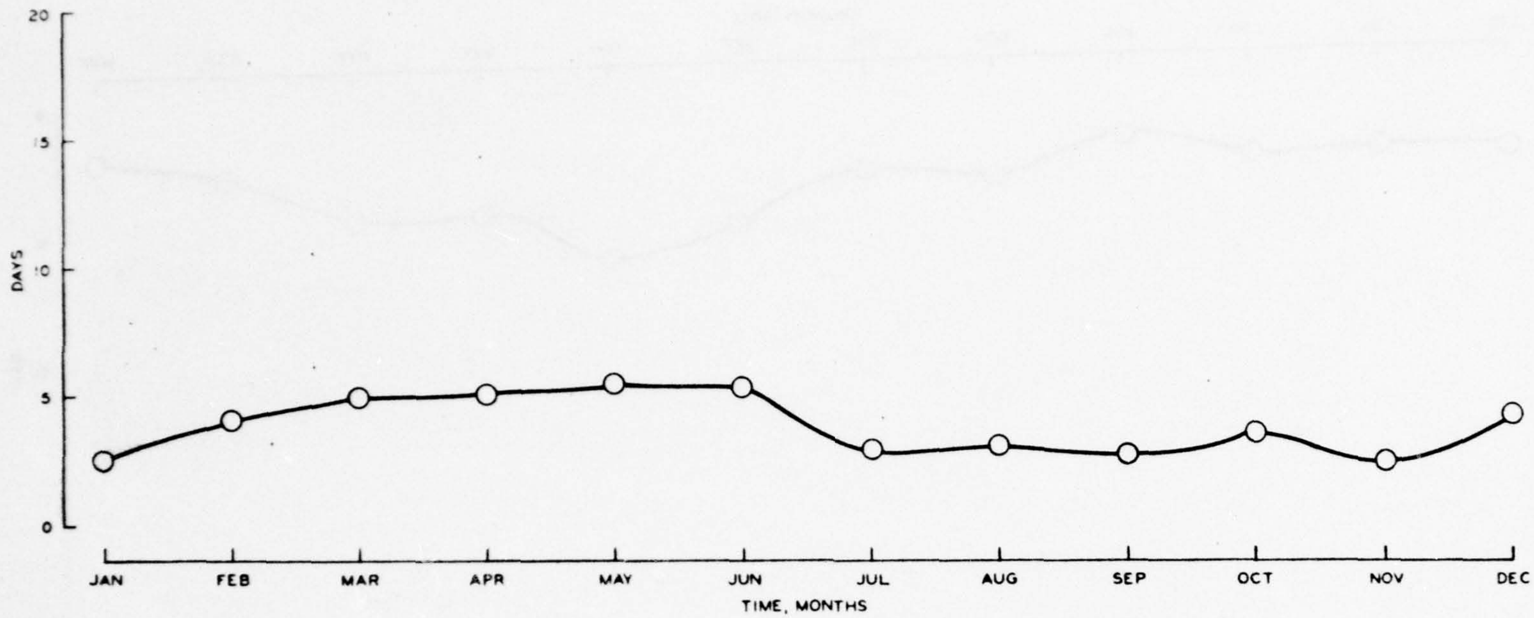

Figure 127. Days/month winds exceed 25-knot velocity, wind station 3

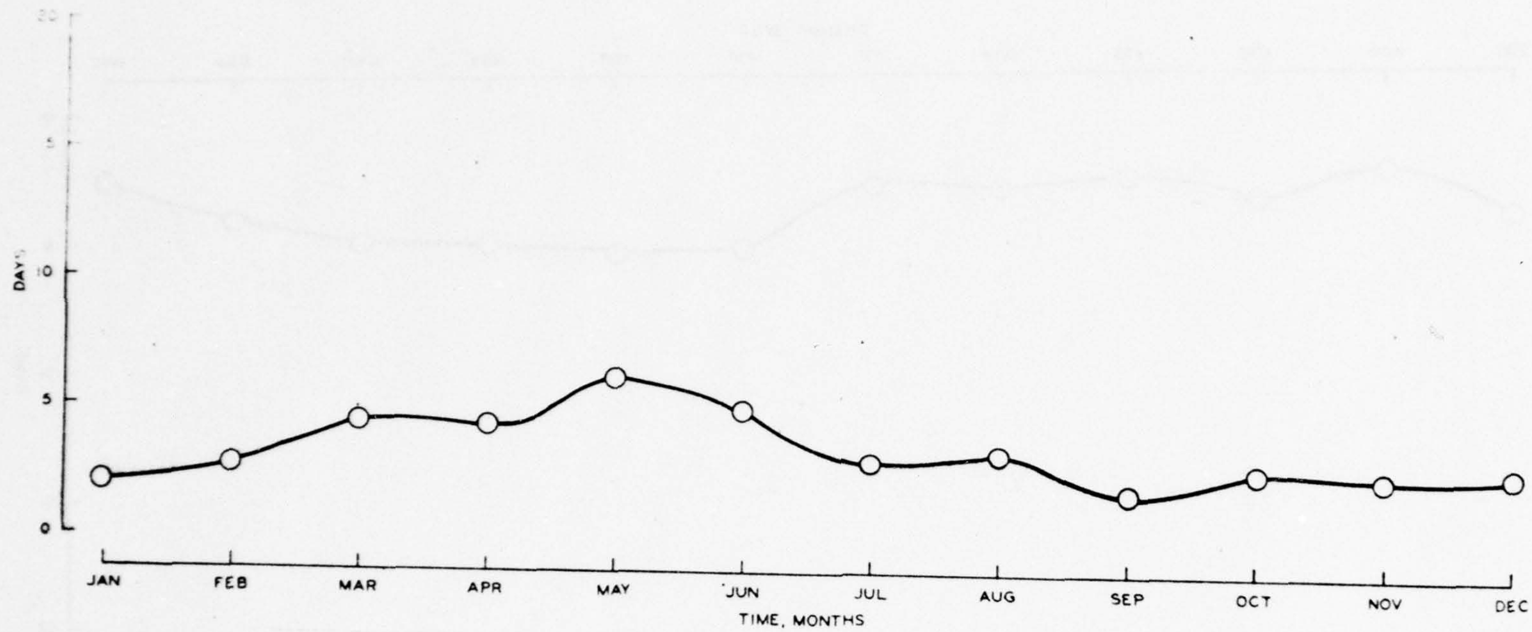

Figure 128. Days/month winds exceed 25-knot velocity, wind station 4

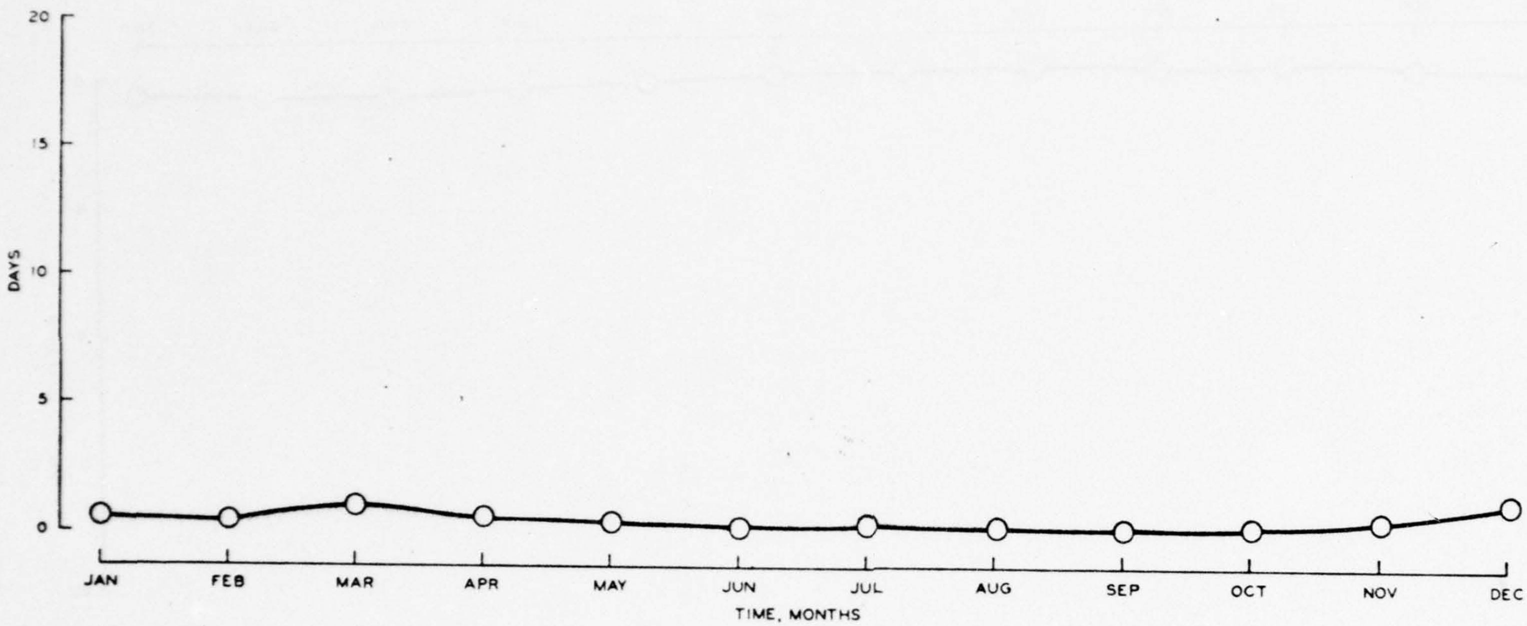

Figure 129. Days/month winds exceed 25-knot velocity, wind station 5

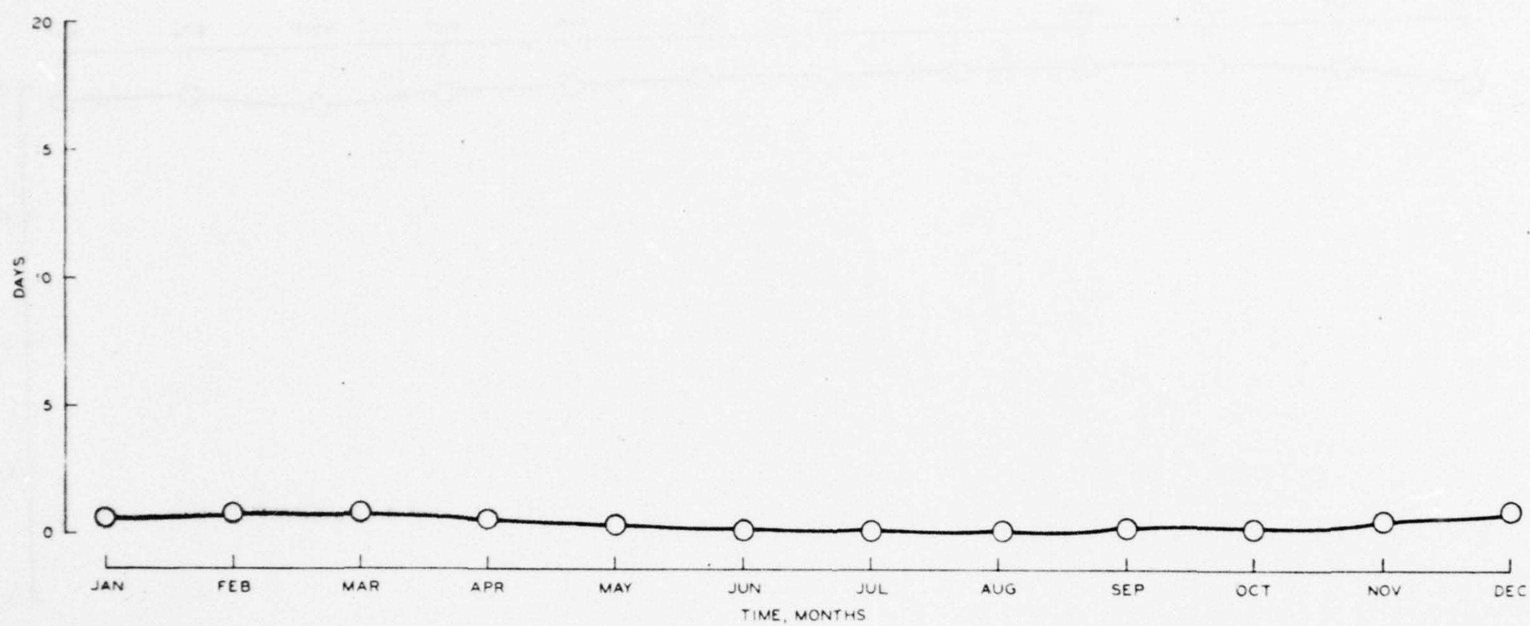

Figure 130. Days/month winds exceed 25-knot velocity, wind station 6

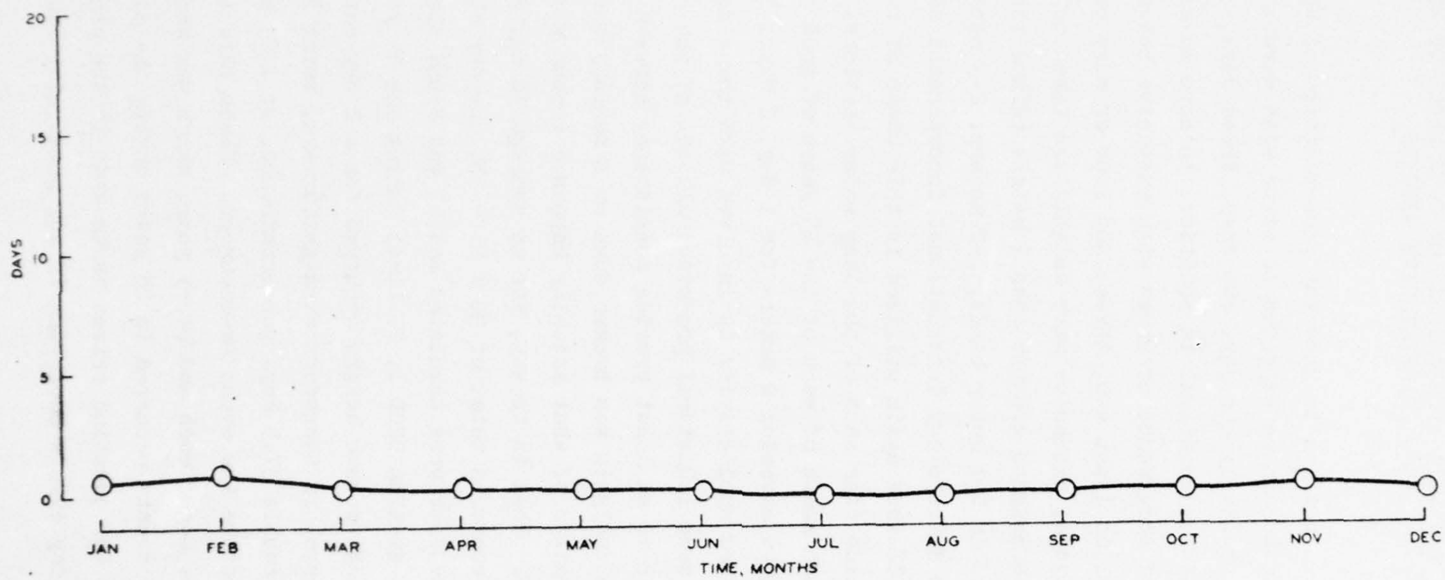

Figure 131. Days/month winds exceed 25-knot velocity, wind station 7

PART VII: PROBABILITY OF OCCURRENCE OF WAVES OF EXCESSIVE HEIGHTS

76. It is desired to know the probabilities of which waves of excessive heights can be expected to occur with durations lasting (on the average) precisely one day, two days, three days, and four or more days. Also, it is required, in addition, to have an estimate of the probability of occurrence of waves with excessive heights lasting at least one day, at least two, three, and four or more consecutive days. For this analysis, excessive wave heights are taken to be those waves occurring with heights greater than 2 meters (since the available data were presented in 0-1 meter bands, 1-2 meters, 2-3 meters, etc.).

77. The Meteorology International Incorporated data of Figures 21 through 32 were again utilized in this phase of the study. A tabulation was made (for each of the deep water stations) of those occurrences for each month of each of the 25 years of good data records when the wave heights exceeded 2 meters for 1 day, 2 days, 3 days, and 4 or more days. Some subjectivity is involved with these determinations; however, the same individual processed all six of the deep water stations in order to at least provide consistency between the stations.

78. The analysis was broken down on a monthly basis and consisted of a consideration of what actually happened versus what possibly could have happened. That is to say, for an average 30 day month and for 25 years of record, a total of 30 x 25 = 750 one day events could have occurred. The data were tabulated and it was found that, for example, in January at station DNOD 1, 20 times during the 25 years of record a storm of excessive wave height occurred for a 1 day duration. The recurrence interval is therefore straightforward, being 750 days divided by 20 events equals 37.5 days per occurrence, or 1.25 months of Januarys must elapse before the event re-occurred. Hence this implies that the event does not occur each and every year, which was known a priori because only 20 events occurred in 25 years during the month of January.

79. Now the question arises as to what is the probability of one of these one day events occurring in any particular January when it is

known that the recurrence interval is 37.5 days. If an event has a true recurrence interval (RI) of 37.5 days, the probability (P) that it will be equaled or exceeded in any one day is:

$$P = 1/RI$$

Since the only possibilities are that the event will or will not occur in any one day, the probability that it will not occur on a given day is (1 - P). From the probability theory, the probability (J) that at least one event which equals or exceeds the 37.5 day event will occur in any series of 30 days is:

$$J = 1 - (1 - P)^{30}$$

So for the example under consideration, the probability is 0.56 that at least one storm will last exactly 1 day during the month of January at DNOD station 1 in any year, on the average.

80. It is frequently not required to know the probability that a storm of excessive heights will last precisely a given number of days, but rather it is desired to know the probability that a storm of excessive heights will last a given number of days or longer. For this reason, the specific durations of 1 day, 2 day, 3 day, and 4 or more day occurrences were accumulated so that in the new analysis, the 3 day occurrences become the sum of the 3 day individual plus the 4 day individual occurrences, and the 2 day occurrences become the sum of the 2 day individual plus the 3 day individual plus the 4 day individual occurrences, etc.

81. The computations are tabulated in Tables 27 through 62 for all six of the DNOD deep water stations, and include the occurrences by month for individual specific durations, the accumulated durations for waves of excessive heights lasting more than a given duration, and the probabilities of occurrences and recurrence intervals for the corresponding events.

82. The data being used for this study is such that it is not possible to accurately transfer the probabilities of occurrence at the deep water stations to the near shore location of the potential LNG terminals. The reasons for this are that the data, as presented in the DNOD reports, are in two forms: (1) the temporal data of Figures 21 through 32, which provide an indication of the wave heights with time (duration) but direction is excluded, and (2) the tabulated data of the DNOD reports which is the frequency distribution of wave heights, periods, directions, and months in terms of the total duration for the 25 years of record. This excludes the nearshore transfer because, for example, a 10 day tabulated value could have been ten 1 day duration storms, five 2 day durations, or two 5 day duration occurrences. It would be necessary to make an acknowledgeably wrong assumption in order to effect a transfer from deep water to the near shore by using the existing data. This assumption would be that the waves approaching the deep water station are uniformly distributed about the point, thereby permitting the probabilities of excessive waves at the deep water station to be reduced by that ratio of excessive wave heights permitted to reach the near shore station through the open window of exposure to the ocean to the total excessive wave heights at the deep water station. This is obviously incorrect since it is known before hand that the greatest majority of high waves come from the northwestern quadrant of the compass. A site which is shielded from a large portion of the northwest approach angle (a site in Monterey Bay, for example) may experience no 4 day durations of excessive heights, where even a small probability as indicated by the above analogy would be incorrect. The sites south of Point Conception which are effectively shielded would be subject to even more uncertainty.

PART VII: SUMMARY OF RESULTS

Conclusions

83. The effect of wind and wave climate was relatively evaluated at 26 potential LNG terminal sites along the coast of California. The analysis did not apply wave refraction theory at any of the sites, so the absolute magnitude of the values obtained at each site are subject to refinement. From other recent work by WES it is known that in 60 ft of water near Mission Bay, California, the refraction effects are such that, depending on the period and direction of approach, the wave heights may be amplified or reduced by as much as 50 percent. Hence, while we have optimized most of the values reported, the actual quantity may be considerably removed from that which is reported.

84. The computations which have been performed are site-specific; i.e., they have been determined by utilizing the situations unique to that one particular location, and the results should not be extrapolated far beyond the respective site, if at all.

85. While researchers who use the same data base should approximate the same conclusions, previous work has been performed using a different data source and it has been observed that the two analyses produced vastly different results (five to six times the magnitude at one particular location). A review of National Marine Consultants data as applied to the Davenport location indicates excessive days of around 180, whereas the application of the DNOD data indicate 29 to be the maximum number of days per year that excessive wave heights occur here, for the 6 ft un-optimized condition. Since DNOD has been the primary source for this study, the conclusions reported are derived from the DNOD data base.

86. On the other hand, for those stations south of Point Conception which are shielded to considerably extent by the channel islands, this study fairly closely approximated those values which have been fragmentarily reported for other locations.

87. It is concluded that, in the absence of breakwater protection and using the assumptions under which this study was conducted, the sites south of Point Conception will, in general, have a higher percentage of operating time than locations to the north. That is not to say, however, that a northern site could not be selected, adequately protected, and effectively used.

88. Wind and sea conditions are not independent, because the occurrence of high seas is usually accompanied by high winds. Hence, downtime caused by high waves should not be merely added to downtime caused by excessive winds. Probably a fairly good first approximation would be to take the larger of the downtimes caused by optimized wave or wind conditions and add to this the supplemental downtime caused by northern and southern swell.

89. Of all the sites investigated, sea conditions accounted for 65 percent of the optimized downtime, northern hemisphere swell accounted for 22 percent, and southern hemisphere swell was responsible for around 13 percent, on the average. Of course, some sites were geographically oriented so that they did not receive any southern swell and others did not receive any northern swell. One site, WES 11a, is exposed only to sea conditions.

90. A summary of the computations for each of the 26 sites is presented in Table 63, and graphically displayed in Figure 132.

Recommendations

90. Any of the proposed sites south of Point Conception appear to be viable potential LNG terminal sites in the absence of additional protective structures (i.e., breakwaters). Furthermore, probably many of the northern sites could be made effective by the expenditure of sufficient funds to provide adequate protection. However, the downtime computations performed in this study are relative values only, in that a pertinent parameter (wave refraction) has been purposefully neglected due to the time constraint for the study.

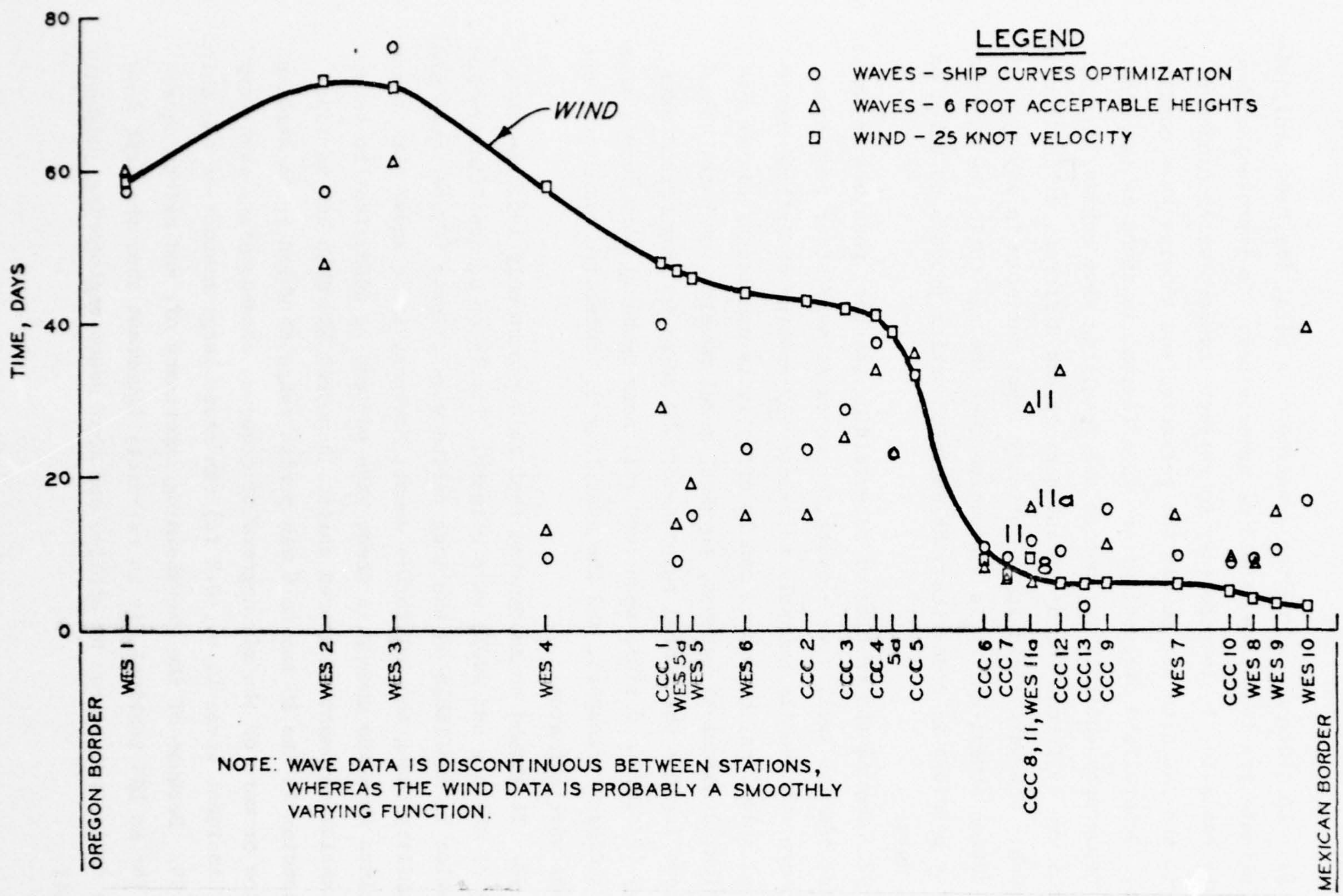

Figure 132. Annual summary, days/year wind and wave conditions exceed specified criteria

91. In order to refine the downtime at a site, the best available wave climate for that site should be ascertained. To improve the wave climate estimate, it is necessary to refract the deep water hindcast data to the LNG site and obtain the refracted and shoaled wave conditions. Generalized discussions are insufficient inasmuch as the localized topography entirely influences the resulting wave regime, and the effects are different for different periods and different directions of approach. The wave field is the primary input variable in any type of wave action study; and it is imperative that the statistics be as correct as possible in order that the decision making process be based on valid data.

92. Beyond the problem of ascertaining the best possible estimate for the sea and swell wave climate, there exist many other problems which are not readily amenable to relatively routine analytical mathematical solutions, but which can be effectively handled by either sophisticated numerical methods, physical model studies, or both. These problems include the moored response of LNG ships to long period wave energy (25 sec to 6 min), scour and fill near terminal structures, long term sediment transport, and the stability of protective structures for various wave climates.

93. It should be recognized that this report only includes estimates of the sea and swell wave climate. Little or no quantitative information is available on the long period wave climate (25 sec to 6 min) variability along the California coast; however, it is known that there are times when the energy in these wave periods is sufficient to cause substantial movement of moored ships. A moored LNG ship has various frequencies in the 25 sec to 6 min period range at which it is resonant for one or more of the six degrees of freedom; consequently, even very small incident waves (i.e., 0.2 ft) can cause large motions of the ship.

94. Because of the overwhelming importance of, and safety necessary for an LNG terminal, it is extremely important that the best possible design procedures be applied and that sound engineering judgments prevail.

REFERENCES

1. Kent, Richard E., Evaluation of Wave and Wind Test Conditions to be Modeled by Delft Hydraulics Laboratory for Western LNG Terminal Company Proposed LNG Marine Facility at Oxnard, California, Technical Memorandum, October 31, 1974, to Western LNG Terminal Co.

2. Meteorology International Incorporated, Deep-Water Wave Statistics for the California Coast, Edition One, February 1977, Volumes 1 through 6, Sacramento, California.

3. Marine Advisers, A Statistical Survey of Ocean Wave Characteristics in Southern California Waters, January 1961.

4. National Marine Consultants, Wave Statistics for Seven Deep Water Stations Along the California Coast, December 1960.

5. Arthur, R. S., "Wave Forecasting and Hindcasting", Proceedings, First Conference on Coastal Engineering, Long Beach, California, pp. 82-87, 1951.

6. Delft Hydraulics Laboratory, Oxnard Marine Terminal, Movements and Forces of a LNG Carrier in Waves, Report on Investigations, June 1975.

7. Oceanographic Services, Inc., Wind and Wave Regime, Port Huenneme, California, June 1974.

8. Delft Hydraulics Laboratory, Point Conception Marine Terminal, Berth Availability of an LNG Facility in Waves, Winds and Currents, Report on Computations, March 1977.

9. Oceanographic Services, Inc., Point Conception Hindcast, Technical Report, February 1977, to Pacific Indonesia Lighting Company.

Table 1

Station WES-1, Crescent City, California

Optimum Terminal Azimuth = $280^{\circ} \pm 10^{\circ}$

Days/Month Wave Conditions Exceed Limiting Criteria*

	Days/Month			
Month	Sea	Northern Swell	Southern Swell	Total
January	6.9	1.8	0.0	8.7
February	5.1	1.6	0.0	6.7
March	5.5	1.5	0.0	7.0
April	3.0	1.1	0.0	4.1
May	1.5	0.7	0.4	2.6
June	1.1	0.4	0.0	1.5
July	0.5	0.2	1.1	1.8
August	0.6	0.4	1.0	2.0
September	1.3	0.6	0.8	2.7
October	3.1	1.1	0.2	4.4
November	5.7	1.5	0.0	7.2
December	6.9	1.8	0.0	8.7
(Annual)	41.2	12.7	3.5	57.4
Percent of Total	71.8	22.1	6.1	100

* Criteria established by model ship response tests of Oxnard Marine Terminal, performed by Delft Hydraulics Laboratory, June 1975.

Table 2

Station WES-2, Point Delgada, California

Optimum Terminal Azimuth = $280^\circ \pm 10^\circ$

Days/Month Wave Conditions Exceed Limiting Criteria*

Month	Days/Month			
	Sea	Northern Swell	Southern Swell	Total
January	6.3	3.1	0.0	9.4
February	4.6	2.8	0.0	7.4
March	4.6	2.4	0.0	7.0
April	2.3	1.6	0.0	3.9
May	1.3	1.1	0.4	2.8
June	0.5	0.6	0.0	1.1
July	0.1	0.3	1.2	1.6
August	0.3	0.4	1.0	1.7
September	0.8	0.8	0.8	2.4
October	2.3	1.6	0.2	4.1
November	5.0	2.3	0.0	7.3
December	5.9	3.0	0.0	8.9
(Annual)	34.0	20.0	3.6	57.6
Percent of Total	59.0	34.7	6.3	100

* Criteria established by model ship response tests of Oxnard Marine Terminal, performed by Delft Hydraulics Laboratory, June 1975.

Table 3

Station WES-3, Point Arena, California

Optimum Terminal Azimuth = $320^\circ \pm 10^\circ$

Days/Month Wave Conditions Exceed Limiting Criteria*

Month	Days/Month			
	Sea	Northern Swell	Southern Swell	Total
January	5.6	3.4	0.0	9.0
February	4.7	3.0	0.0	7.7
March	5.3	3.0	0.0	8.3
April	4.1	2.3	0.0	6.4
May	3.6	1.6	0.5	5.7
June	3.2	1.0	0.0	4.2
July	2.4	0.7	1.6	4.7
August	2.7	0.8	1.3	4.8
September	1.7	1.2	1.1	4.0
October	2.4	2.2	0.3	4.9
November	4.6	3.1	0.0	7.7
December	5.4	3.4	0.0	8.8
(Annual)	45.7	25.7	4.8	76.2
Percent of Total	60.0	33.7	6.3	100

* Criteria established by model ship response tests of Oxnard Marine Terminal, performed by Delft Hydraulics Laboratory, June 1975.

Table 4

Station WES-4, Point Reyes, California

Optimum Terminal Azimuth = $200^{\circ} \pm 10^{\circ}$

Days/Month Wave Conditions Exceed Limiting Criteria*

	Days/Month			
Month	Sea	Northern Swell	Southern Swell	Total
January	1.8	0.1	0.0	1.9
February	1.6	0.1	0.0	1.7
March	0.8	0.1	0.0	0.9
April	0.4	0.1	0.0	0.5
May	0.1	0.1	0.0	0.2
June	0.0	0.1	0.0	0.1
July	0.0	0.1	0.0	0.1
August	0.0	0.1	0.0	0.1
September	0.1	0.1	0.0	0.2
October	0.5	0.1	0.0	0.6
November	1.4	0.1	0.0	1.5
December	1.5	0.1	0.0	1.6
(Annual)	8.2	1.2	0.0	9.4
Percent of Total	87.2	12.8	0.0	100

* Criteria established by model ship response tests of Oxnard Marine Terminal, performed by Delft Hydraulics Laboratory, June 1975.

Table 5

Station CCC-1, Davenport, California

Optimum Terminal Azimuth = $300^{\circ} \pm 10^{\circ}$

Days/Month Wave Conditions Exceed Limiting Criteria*

Month	Days/Month			
	Sea	Northern Swell	Southern Swell	Total
January	2.8	1.5	0.0	4.3
February	2.4	1.4	0.0	3.8
March	2.5	1.2	0.0	3.7
April	2.0	0.9	0.0	2.9
May	2.1	0.6	0.5	3.2
June	1.9	0.3	0.0	2.2
July	1.7	0.3	1.6	3.6
August	1.8	0.5	1.3	3.6
September	1.1	0.6	1.1	2.8
October	1.2	0.9	0.3	2.4
November	2.1	1.4	0.0	3.5
December	2.4	1.6	0.0	4.0
(Annual)	24.0	11.2	4.8	40.0
Percent of Total	60.0	28.0	12.0	100

* Criteria established by model ship response tests of Oxnard Marine Terminal, performed by Delft Hydraulics Laboratory, June 1975.

Table 6

Station WES-5a, Soquel Point, California

Optimum Terminal Azimuth = $240^{\circ} \pm 10^{\circ}$

Days/Month Wave Conditions Exceed Limiting Criteria*

Month	Days/Month			
	Sea	Northern Swell	Southern Swell	Total
January	1.5	0.2	0.0	1.7
February	1.2	0.2	0.0	1.4
March	1.0	0.2	0.0	1.2
April	0.7	0.1	0.0	0.8
May	0.3	0.1	0.0	0.4
June	0.1	0.1	0.0	0.2
July	0.1	0.1	0.0	0.2
August	0.1	0.1	0.0	0.2
September	0.1	0.1	0.0	0.2
October	0.4	0.2	0.0	0.6
November	1.0	0.2	0.0	1.2
December	1.2	0.2	0.0	1.4
(Annual)	7.7	1.8	0.0	9.5
Percent of Total	81.0	19.0	0.0	100

* Criteria established by model ship response tests of Oxnard Marine Terminal, performed by Delft Hydraulics Laboratory, June 1975.

Table 7

Station WES-5, Moss Landing, Caliornia

Optimum Terminal Azimuth = $280^\circ \pm 10^\circ$

Days/Month Wave Conditions Exceed Limiting Criteria*

Month	Days/Month			
	Sea	Northern Swell	Southern Swell	Total
January	0.6	0.8	0.0	1.4
February	0.5	0.7	0.0	1.2
March	0.8	0.6	0.0	1.4
April	0.7	0.4	0.0	1.1
May	0.8	0.3	0.3	1.4
June	0.7	0.1	0.0	0.8
July	0.6	0.1	0.6	1.3
August	0.6	0.2	0.9	1.7
September	0.4	0.3	0.6	1.3
October	0.3	0.5	0.1	0.9
November	0.5	0.7	0.0	1.2
December	0.5	0.8	0.0	1.3
(Annual)	7.0	5.5	2.5	15.0
Percent of Total	46.7	36.7	16.6	100

* Criteria established by model ship response tests of Oxnard Marine Terminal, performed by Delft Hydraulics Laboratory, June 1975.

Table 8

Station WES-6, Partington Point, California

Optimum Terminal Azimuth = $280^\circ \pm 10^\circ$

Days/Month Wave Conditions Exceed Limiting Criteria*

Month	Days/Month			
	Sea	Northern Swell	Southern Swell	Total
January	1.6	1.0	0.0	2.6
February	1.3	0.8	0.0	2.1
March	1.6	0.7	0.0	2.3
April	1.1	0.5	0.0	1.6
May	1.1	0.3	0.4	1.8
June	1.2	0.1	0.0	1.3
July	1.0	0.1	1.3	2.4
August	0.9	0.2	1.1	2.2
September	0.6	0.4	0.9	1.9
October	0.6	0.5	0.2	1.3
November	1.1	0.8	0.0	1.9
December	1.3	0.9	0.0	2.2
(Annual)	13.4	6.3	3.9	23.6
Percent of Total	56.8	26.7	16.5	100

* Criteria established by model ship response tests of Oxnard Marine Terminal, performed by Delft Hydraulics Laboratory, June 1975.

Table 9

Station CCC-2, San Simeon Point, California

Optimum Terminal Azimuth = $280^{\circ} \pm 10^{\circ}$

Days/Month Wave Conditions Exceed Limiting Criteria*

Month	Days/Month Sea	Northern Swell	Southern Swell	Total
January	2.1	1.0	0.0	3.1
February	1.7	0.9	0.0	2.6
March	1.5	0.7	0.0	2.2
April	1.2	0.4	0.0	1.6
May	0.9	0.3	0.4	1.6
June	0.8	0.1	0.0	0.9
July	0.6	0.1	1.3	2.0
August	0.5	0.2	1.1	1.8
September	0.4	0.4	0.9	1.7
October	0.6	0.5	0.2	1.3
November	1.4	0.7	0.0	2.1
December	1.7	0.9	0.0	2.6
(Annual)	13.4	6.2	3.9	23.5
Percent of Total	57.0	26.4	16.6	100

* Criteria established by model ship response tests of Oxnard Marine Terminal, performed by Delft Hydraulics Laboratory, June 1975.

Table 10

Station CCC-3, Point Estero, California

Optimum Terminal Azimuth = $300^{\circ} \pm 10^{\circ}$

Days/Month Wave Conditions Exceed Limiting Criteria*

	Days/Month			
Month	Sea	Northern Swell	Southern Swell	Total
January	1.4	1.1	0.0	2.5
February	1.2	1.0	0.0	2.2
March	0.9	0.8	0.0	1.7
April	1.4	0.7	0.0	2.1
May	1.9	0.5	0.5	2.9
June	1.9	0.3	0.0	2.2
July	1.8	0.3	1.4	3.5
August	1.7	0.4	1.2	3.3
September	1.0	0.5	1.0	2.5
October	0.7	0.7	0.2	1.6
November	1.0	1.0	0.0	2.0
December	1.1	1.1	0.0	2.2
(Annual)	16.0	8.4	4.3	28.7
Percent of Total	55.7	29.3	15.0	100

* Criteria established by model ship response tests of Oxnard Marine Terminal, performed by Delft Hydraulics Laboratory, June 1975.

Table 11

Station CCC-4, Point Buchon, California

Optimum Terminal Azimuth = $310^{\circ} \pm 10^{\circ}$

Days/Month Wave Conditions Exceed Limiting Criteria*

Month	Days/Month Sea	Northern Swell	Southern Swell	Total
January	1.6	1.3	0.0	2.9
February	1.4	1.1	0.0	2.5
March	1.7	1.0	0.0	2.7
April	1.8	0.8	0.0	2.6
May	2.8	0.6	0.5	3.9
June	3.0	0.4	0.0	3.4
July	2.9	0.4	1.4	4.7
August	2.7	0.6	1.2	4.5
September	1.5	0.6	1.0	3.1
October	1.0	0.9	0.2	2.1
November	1.2	1.2	0.0	2.4
December	1.3	1.3	0.0	2.6
(Annual)	22.9	10.2	4.3	37.4
Percent of Total	61.2	27.3	11.5	100

* Criteria established by model ship response tests of Oxnard Marine Terminal, performed by Delft Hydraulics Laboratory, June 1975.

Table 12

Station CCC-5a, Oso Flaco Lagoon, California

Optimum Terminal Azimuth = $300^{\circ} \pm 10^{\circ}$

Days/Month Wave Conditions Exceed Limiting Criteria*

Month	Days/Month			
	Sea	Northern Swell	Southern Swell	Total
January	0.8	1.2	0.0	2.0
February	0.7	1.0	0.0	1.7
March	0.9	0.9	0.0	1.8
April	0.9	0.7	0.0	1.6
May	1.3	0.4	0.5	2.2
June	1.3	0.2	0.0	1.5
July	1.3	0.2	1.4	2.9
August	1.2	0.2	1.2	2.6
September	0.7	0.4	1.0	2.1
October	0.5	0.6	0.2	1.3
November	0.5	1.0	0.0	1.5
December	0.6	1.2	0.0	1.8
(Annual)	10.7	8.0	4.3	23.0
Percent of Total	46.5	34.8	18.7	100

* Criteria established by model ship response tests of Oxnard Marine Terminal, performed by Delft Hydraulics Laboratory, June 1975.

Table 13

Station CCC-5, Guadalupe Dunes, California

Optimum Terminal Azimuth = $310^{\circ} \pm 10^{\circ}$

Days/Month Wave Conditions Exceed Limiting Criteria*

Month	Days/Month			
	Sea	Northern Swell	Southern Swell	Total
January	1.1	1.2	0.0	2.3
February	1.0	1.1	0.0	2.1
March	1.5	1.0	0.0	2.5
April	1.5	0.8	0.0	2.3
May	2.5	0.6	0.5	3.6
June	2.6	0.4	0.0	3.0
July	2.5	0.4	1.4	4.3
August	2.4	0.5	1.2	4.1
September	1.3	0.6	1.0	2.9
October	0.8	0.8	0.2	1.8
November	0.8	1.1	0.0	1.9
December	0.9	1.3	0.0	2.2
(Annual)	18.9	9.8	4.3	33.0
Percent of Total	57.3	29.7	13.0	100

* Criteria established by model ship response tests of Oxnard Marine Terminal, performed by Delft Hydraulics Laboratory, June 1975.

Table 14

Station CCC-6, Point Conception, California

Optimum Terminal Azimuth = $250^{\circ} \pm 10^{\circ}$

Days/Month Wave Conditions Exceed Limiting Criteria*

	Days/Month			
Month	Sea	Northern Swell	Southern Swell	Total
January	1.3	0.1	0.0	1.4
February	2.1	0.1	0.0	2.2
March	1.8	0.1	0.0	1.9
April	1.2	0.1	0.0	1.3
May	0.7	0.1	0.0	0.8
June	0.2	0.1	0.0	0.3
July	0.2	0.1	0.0	0.3
August	0.0	0.1	0.0	0.1
September	0.1	0.1	0.0	0.2
October	0.6	0.1	0.0	0.7
November	0.3	0.1	0.0	0.4
December	0.7	0.1	0.0	0.8
(Annual)	9.2	1.2	0.0	10.4
Percent of Total	88.5	11.5	0.0	100

* Criteria established by model ship response tests of Oxnard Marine Terminal, performed by Delft Hydraulics Laboratory, June 1975.

Table 15

Station CCC-7, Tajiguas, California

Optimum Terminal Azimuth = $250^{\circ} \pm 10^{\circ}$

Days/Month Wave Conditions Exceed Limiting Criteria*

Month	Days/Month: Sea	Northern Swell	Southern Swell	Total
January	1.2	0.1	0.0	1.3
February	2.0	0.1	0.0	2.1
March	1.7	0.1	0.0	1.8
April	1.1	0.1	0.0	1.2
May	0.6	0.1	0.0	0.7
June	0.2	0.1	0.0	0.3
July	0.1	0.1	0.0	0.2
August	0.0	0.1	0.0	0.1
September	0.0	0.1	0.0	0.1
October	0.5	0.1	0.0	0.6
November	0.2	0.1	0.0	0.3
December	0.6	0.1	0.0	0.7
(Annual)	8.2	1.2	0.0	9.4
Percent of Total	87.2	12.8	0.0	100

* Criteria established by model ship response tests of Oxnard Marine Terminal, performed by Delft Hydraulics Laboratory, June 1975.

Table 16

Station CCC-8, Los Pueblos Ranch, California

Optimum Terminal Azimuth = 250° ± 10°

Days/Month Wave Conditions Exceed Limiting Criteria*

Month	Days/Month			
	Sea	Northern Swell	Southern Swell	Total
January	1.2	0.1	0.0	1.3
February	2.0	0.1	0.0	2.1
March	1.7	0.1	0.0	1.8
April	1.1	0.1	0.0	1.2
May	0.6	0.1	0.0	0.7
June	0.2	0.1	0.0	0.3
July	0.2	0.1	0.0	0.1
August	0.0	0.1	0.0	0.1
September	0.1	0.1	0.0	0.2
October	0.5	0.1	0.0	0.6
November	0.3	0.1	0.0	0.4
December	0.7	0.1	0.0	0.8
(Annual)	8.6	1.2	0.0	9.8
Percent of Total	87.8	12.2	0.0	100

* Criteria established by model ship response tests of Oxnard Marine Terminal, performed by Delft Hydraulics Laboratory, June 1975.

Table 17

Station CCC-9, Deer Canyon, California

Optimum Terminal Azimuth = $270^{\circ} \pm 10^{\circ}$

Days/Month Wave Conditions Exceed Limiting Criteria*

Month	Days/Month			
	Sea	Northern Swell	Southern Swell	Total
January	1.7	0.1	0.0	1.8
February	1.5	0.1	0.0	1.6
March	1.4	0.1	0.0	1.5
April	1.2	0.1	0.0	1.3
May	0.9	0.1	0.3	1.3
June	0.9	0.1	0.0	1.0
July	0.7	0.1	0.8	1.6
August	0.4	0.1	0.7	1.2
September	0.6	0.1	0.6	1.3
October	0.5	0.1	0.2	0.8
November	1.1	0.1	0.0	1.2
December	1.2	0.1	0.0	1.3
(Annual)	12.1	1.2	2.6	15.9
Percent of Total	76.1	7.5	16.4	100

* Criteria established by model ship response tests of Oxnard Marine Terminal, performed by Delft Hydraulics Laboratory, June 1975.

Table 18

Station WES-7, Redondo Beach, California

Optimum Terminal Azimuth = $280^{\circ} \pm 10^{\circ}$

Days/Month Wave Conditions Exceed Limiting Criteria*

	Days/Month			
Month	Sea	Northern Swell	Southern Swell	Total
January	0.4	0.1	0.0	0.5
February	0.4	0.1	0.0	0.5
March	0.6	0.1	0.0	0.7
April	0.6	0.1	0.0	0.7
May	0.8	0.1	0.0	0.9
June	0.8	0.1	0.3	1.2
July	0.7	0.1	0.3	1.1
August	0.5	0.1	0.7	1.3
September	0.4	0.1	0.7	1.2
October	0.3	0.1	0.3	0.7
November	0.3	0.1	0.0	0.4
December	0.3	0.1	0.0	0.4
(Annual)	6.1	1.2	2.3	9.6
Percent of Total	63.5	12.5	24.0	100

* Criteria established by model ship response tests of Oxnard Marine Terminal, performed by Delft Hydraulics Laboratory, June 1975.

Table 19

Station CCC-10, Camp Pendelton, California

Optimum Terminal Azimuth = $280^{\circ} \pm 10^{\circ}$

Days/Month Wave Conditions Exceed Limiting Criteria*

Month	Days/Month Sea	Northern Swell	Southern Swell	Total
January	0.2	0.1	0.0	0.3
February	0.2	0.1	0.0	0.3
March	0.3	0.1	0.0	0.4
April	0.3	0.1	0.0	0.4
May	0.4	0.1	0.4	0.9
June	0.4	0.1	0.0	0.5
July	0.4	0.1	1.3	1.8
August	0.4	0.1	1.1	1.6
September	0.2	0.1	0.9	1.2
October	0.2	0.1	0.2	0.5
November	0.1	0.1	0.0	0.2
December	0.1	0.1	0.0	0.2
(Annual)	3.2	1.2	3.9	8.3
Percent of Total	38.6	14.5	46.9	100

* Criteria established by model ship response tests of Oxnard Marine Terminal, performed by Delft Hydraulics Laboratory, June 1975.

AD-A049 883 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MISS F/G 13/10
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Table 20

Station WES-8, Oceanside, California

Optimum Terminal Azimuth = $290^{\circ} \pm 10^{\circ}$

Days/Month Wave Conditions Exceed Limiting Criteria*

	Days/Month			
Month	Sea	Northern Swell	Southern Swell	Total
January	0.2	0.1	0.0	0.3
February	0.2	0.1	0.0	0.3
March	0.3	0.1	0.0	0.4
April	0.3	0.1	0.0	0.4
May	0.4	0.1	0.5	1.0
June	0.4	0.1	0.0	0.5
July	0.4	0.1	1.5	2.0
August	0.3	0.1	1.2	1.6
September	0.2	0.1	1.0	1.3
October	0.2	0.1	0.2	0.5
November	0.1	0.1	0.0	0.2
December	0.1	0.1	0.0	0.2
(Annual)	3.1	1.2	4.4	8.7
Percent of Total	35.6	13.8	50.6	100

* Criteria established by model ship response tests of Oxnard Marine Terminal, performed by Delft Hydraulics Laboratory, June 1975.

Table 21

Station WES-9, Encinitas, California

Optimum Terminal Azimuth = $300^{\circ} \pm 10^{\circ}$

Days/Month Wave Conditions Exceed Limiting Criteria*

	Days/Month			
Month	Sea	Northern Swell	Southern Swell	Total
January	0.2	0.2	0.0	0.4
February	0.2	0.2	0.0	0.4
March	0.4	0.1	0.0	0.5
April	0.4	0.1	0.0	0.5
May	0.5	0.1	0.5	1.1
June	0.6	0.1	0.0	0.7
July	0.6	0.1	1.4	2.1
August	0.5	0.1	1.2	1.8
September	0.4	0.1	1.0	1.5
October	0.2	0.1	0.3	0.6
November	0.2	0.2	0.0	0.4
December	0.1	0.2	0.0	0.3
(Annual)	4.3	1.6	4.4	10.3
Percent of Total	41.7	15.5	42.8	100

* Criteria established by model ship response tests of Oxnard Marine Terminal, performed by Delft Hydraulics Laboratory, June 1975.

Table 22

Station WES-10, Mission Bay, California

Optimum Terminal Azimuth = $310^\circ \pm 10^\circ$

Days/Month Wave Conditions Exceed Limiting Criteria*

Month	Days/Month Sea	Northern Swell	Southern Swell	Total
January	0.5	0.2	0.0	0.7
February	0.6	0.2	0.0	0.8
March	0.9	0.2	0.0	1.1
April	1.1	0.1	0.0	1.2
May	1.3	0.1	0.5	1.9
June	1.3	0.1	0.0	1.4
July	1.2	0.1	1.4	2.7
August	1.2	0.1	1.2	2.5
September	0.9	0.1	1.0	2.0
October	0.7	0.2	0.3	1.2
November	0.5	0.2	0.0	0.7
December	0.4	0.2	0.0	0.6
(Annual)	10.6	1.8	4.4	16.8
Percent of Total	63.1	10.7	26.2	100

* Criteria established by model ship response tests of Oxnard Marine Terminal, performed by Delft Hydraulics Laboratory, June 1975.

Table 23

Station CCC-11, Santa Rosa Island - CCC Location, California

Optimum Terminal Azimuth = $330^{\circ} \pm 10^{\circ}$

Days/Month Wave Conditions Exceed Limiting Criteria*

	Days/Month			
Month	Sea	Northern Swell	Southern Swell	Total
January	0.3	0.5	0.0	0.8
February	0.3	0.5	0.0	0.8
March	0.6	0.4	0.0	1.0
April	0.7	0.4	0.0	1.1
May	0.9	0.3	0.0	1.2
June	0.9	0.3	0.0	1.2
July	0.9	0.2	0.0	1.1
August	1.0	0.2	0.0	1.2
September	0.7	0.2	0.0	0.9
October	0.5	0.3	0.0	0.8
November	0.3	0.6	0.0	0.9
December	0.2	0.6	0.0	0.8
(Annual)	7.3	4.5	0.0	11.8
Percent of Total	61.9	38.1	0.0	100

* Criteria established by model ship response tests of Oxnard Marine Terminal, performed by Delft Hydraulics Laboratory, June 1975.

Table 24

Station WES-11a, Santa Rosa Island - WES Location, California

Optimum Terminal Azimuth = $350^{\circ} \pm 10^{\circ}$

Days/Month Wave Conditions Exceed Limiting Criteria*

	Days/Month			
Month	Sea	Northern Swell	Southern Swell	Total
January	0.2	0.0	0.0	0.2
February	0.2	0.0	0.0	0.2
March	0.5	0.0	0.0	0.5
April	0.6	0.0	0.0	0.6
May	0.8	0.0	0.0	0.8
June	0.8	0.0	0.0	0.8
July	0.8	0.0	0.0	0.8
August	0.9	0.0	0.0	0.9
September	0.6	0.0	0.0	0.6
October	0.4	0.0	0.0	0.4
November	0.2	0.0	0.0	0.2
December	0.1	0.0	0.0	0.1
(Annual)	6.1	0.0	0.0	6.1
Percent of Total	100	0.0	0.0	100

* Criteria established by model ship response tests of Oxnard Marine Terminal, performed by Delft Hydraulics Laboratory, June 1975.

Table 25

Station CCC-12, Santa Cruz Island - North, California

Optimum Terminal Azimuth = $310^{\circ} \pm 10^{\circ}$

Days/Month Wave Conditions Exceed Limiting Criteria*

Month	Days/Month Sea	Northern Swell	Southern Swell	Total
January	0.2	0.5	0.0	0.7
February	0.3	0.5	0.0	0.8
March	0.6	0.3	0.0	0.9
April	0.7	0.2	0.0	0.9
May	1.0	0.1	0.0	1.1
June	1.0	0.1	0.0	1.1
July	1.0	0.1	0.0	1.1
August	1.0	0.1	0.0	1.1
September	0.7	0.1	0.0	0.8
October	0.5	0.1	0.0	0.6
November	0.2	0.3	0.0	0.5
December	0.2	0.4	0.0	0.6
(Annual)	7.4	2.8	0.0	10.2
Percent of Total	72.5	27.5	0.0	100

* Criteria established by model ship response tests of Oxnard Marine Terminal, performed by Delft Hydraulics Laboratory, June 1975.

Table 26

Station CCC-13, Santa Cruz Island - East, California

Optimum Terminal Azimuth = 200° ± 10°

Days/Month Wave Conditions Exceed Limiting Criteria*

	Days/Month			
Month	Sea	Northern Swell	Southern Swell	Total
January	0.5	0.1	0.0	0.6
February	0.4	0.1	0.0	0.5
March	0.3	0.1	0.0	0.4
April	0.1	0.1	0.0	0.2
May	0.0	0.1	0.0	0.1
June	0.0	0.1	0.0	0.1
July	0.0	0.1	0.0	0.1
August	0.0	0.1	0.0	0.1
September	0.0	0.1	0.0	0.1
October	0.1	0.1	0.0	0.2
November	0.3	0.1	0.0	0.4
December	0.3	0.1	0.0	0.4
(Annual)	2.0	1.2	0.0	3.2
Percent of Total	62.5	37.5	0.0	100

* Criteria established by model ship response tests of Oxnard Marine Terminal, performed by Delft Hydraulics Laboratory, June 1975.

Table 27

Deep Water Station DNOD 1

Monthly Total Occurrences of Wave Heights 6 Ft or Greater for Specific Consecutive Days Duration*

Month	Duration: 1 Day	2 Days	3 Days	4 Days +
January	20	29	28	42
February	47	56	19	28
March	34	42	29	37
April	42	55	25	13
May	32	43	21	8
June	37	42	10	9
July	40	43	16	5
August	21	19	6	5
September	21	21	2	1
October	25	30	16	7
November	24	36	27	27
December	37	43	23	43
(Annual)	380	459	222	225

* 25 years of record, 1950-1974.

Table 28

Deep Water Station DNOD 1

Recurrence Interval (Months) of Wave Heights 6 Ft or Greater for Specific Consecutive Days Duration

Month	Duration			
	1 Day	2 Days	3 Days	4 Days +
January	1.25	0.86	0.89	0.60
February	0.53	0.45	1.32	0.89
March	0.74	0.60	0.86	0.68
April	0.60	0.45	1.00	1.92
May	0.78	0.58	1.19	3.13
June	0.68	0.60	2.50	2.78
July	0.63	0.58	1.56	5.00
August	1.19	1.32	4.17	5.00
September	1.19	1.19	12.50	25.00
October	1.00	0.83	1.56	3.57
November	1.04	0.69	0.93	0.93
December	0.68	0.58	1.09	0.58

Table 29

Deep Water Station DNOD 1

Probability of Occurrence of Wave Heights 6 Ft or Greater for Specific Consecutive Days Duration*

Month	Duration			
	1 Day	2 Days	3 Days	4 Days +
January	.56	.69	.68	.82
February	.86	.90	.54	.68
March	.75	.82	.69	.78
April	.82	.90	.64	.41
May	.73	.83	.57	.28
June	.78	.82	.33	.30
July	.81	.83	.48	.18
August	.57	.54	.21	.18
September	.57	.57	.08	.04
October	.64	.71	.48	.25
November	.62	.77	.67	.67
December	.78	.83	.61	.83

* Probability shown is the degree of expectation that a specific duration will occur each year, on the average.

Table 30

Deep Water Station DNOD 1

Monthly Total Occurrences of Wave Heights 6 Ft or

Greater for Consecutive Days Duration Exceeding Specific Values*

Month	Duration 1 Day +	2 Days +	3 Days +	4 Days +
January	119	99	70	42
February	150	103	47	28
March	142	108	66	37
April	135	93	38	13
May	104	72	29	8
June	98	61	19	9
July	104	64	21	5
August	51	30	11	5
September	45	24	3	1
October	78	53	23	7
November	114	90	54	27
December	146	109	66	43
(Annual)	1286	906	447	225

* 25 years of record, 1950-1974.

Table 31

Deep Water Station DNOD 1

Recurrence Interval (Days) of Wave Heights 6 Ft or Greater for Consecutive Days Duration Exceeding Specific Values

Month	Duration			
	1 Day +	2 Days +	3 Days +	4 Days +
January	6.3	7.6	10.7	17.9
February	5.0	7.3	16.0	26.8
March	5.3	6.9	11.4	20.3
April	5.6	8.1	19.7	57.7
May	7.2	10.4	25.9	93.8
June	7.7	12.3	39.5	83.3
July	7.2	11.7	35.7	150.0
August	14.7	25.0	68.2	150.0
September	16.7	31.3	250.0	750.0
October	9.6	14.2	32.6	107.1
November	6.6	8.3	13.9	27.8
December	5.1	6.9	11.4	17.4

Table 32

Deep Water Station DNOD 1

Probability of Occurrence of Wave Heights 6 Ft or Greater for Consecutive Days Duration Exceeding Specific Values*

Month	Duration 1 Day +	2 Days +	3 Days +	4 Days +
January	.99	.99	.95	.82
February	.99	.99	.86	.68
March	.99	.99	.94	.78
April	.99	.98	.79	.41
May	.99	.95	.69	.28
June	.99	.92	.54	.30
July	.99	.93	.57	.18
August	.88	.71	.36	.18
September	.84	.62	.11	.04
October	.96	.89	.61	.25
November	.99	.98	.89	.67
December	.99	.99	.94	.83

* Probability shown is the degree of expectation that a specific duration will be exceeded each year, on the average.

Table 33

Deep Water Station DNOD 2

Monthly Total Occurrences of Wave Heights 6 Ft or Greater for Specific Consecutive Days Duration*

Month	Duration 1 Day	2 Days	3 Days	4 Days +
January	30	45	15	42
February	30	44	19	29
March	42	56	26	32
April	35	48	31	9
May	38	49	24	8
June	45	52	14	3
July	31	32	12	3
August	15	17	4	3
September	14	14	1	1
October	26	29	14	5
November	38	47	24	20
December	38	54	27	33
(Annual)	382	487	211	188

* 25 years of record, 1950-1974.

Table 34

Deep Water Station DNOD 2

Recurrence Interval (Months) of Wave Heights 6 Ft or Greater for Specific Consecutive Days Duration

Month	Duration			
	1 Day	2 Days	3 Days	4 Days +
January	0.83	0.56	1.67	0.60
February	0.83	0.57	1.32	0.86
March	0.60	0.45	0.96	0.78
April	0.71	0.52	0.81	2.78
May	0.66	0.51	1.04	3.13
June	0.56	0.48	1.79	8.33
July	0.81	0.78	2.08	8.33
August	1.67	1.47	6.25	8.33
September	1.79	1.79	25.00	25.00
October	0.96	0.86	1.79	5.00
November	0.66	0.53	1.04	1.25
December	0.66	0.46	0.93	0.76

Table 35

Deep Water Station DNOD 2

Probability of Occurrence of Wave Heights 6 Ft or Greater for Specific Consecutive Days Duration*

Month	Duration			
	1 Day	2 Days	3 Days	4 Days +
January	.71	.84	.45	.82
February	.71	.84	.54	.69
March	.82	.90	.65	.73
April	.76	.86	.72	.30
May	.79	.87	.62	.28
June	.84	.88	.43	.11
July	.72	.73	.38	.11
August	.45	.50	.15	.11
September	.43	.43	.04	.04
October	.65	.69	.43	.18
November	.79	.86	.62	.56
December	.79	.89	.67	.74

* Probability shown is the degree of expectation that a specific duration will occur each year, on the average.

Table 36

Deep Water Station DNOD 2

Monthly Total Occurrences of Wave Heights 6 Ft or Greater for Consecutive Days Duration Exceeding Specific Values*

Month	Duration 1 Day +	2 Days +	3 Days +	4 Days +
January	132	102	57	42
February	122	92	48	29
March	156	114	58	32
April	123	88	40	9
May	119	81	32	8
June	114	69	17	3
July	78	47	15	3
August	39	24	7	3
September	30	16	2	1
October	74	48	19	5
November	130	92	45	20
December	152	114	60	33
(Annual)	1269	887	400	188

* 25 years of record, 1950-1974.

Table 37

Deep Water Station DNOD 2

Recurrence Interval (Days) of Wave Heights 6 Ft or Greater for Consecutive Days Duration Exceeding Specific Values

Month	Duration			
	1 Day +	2 Days +	3 Days +	4 Days +
January	5.7	7.4	13.2	17.9
February	6.1	8.2	15.6	25.9
March	4.8	6.6	12.9	23.4
April	6.1	8.5	18.8	83.3
May	6.3	9.3	23.4	93.8
June	6.6	10.9	44.1	250.0
July	9.6	16.0	50.0	250.0
August	19.2	31.3	107.1	250.0
September	25.0	46.9	375.0	750.0
October	10.1	15.6	39.5	150.0
November	5.8	8.2	16.7	37.5
December	4.9	6.6	12.5	22.7

Table 38

Deep Water Station DNOD 2

Probability of Occurrence of Wave Heights 6 Ft or

Greater for Consecutive Days Duration Exceeding Specific Values*

Month	Duration			
	1 Day +	2 Days +	3 Days +	4 Days +
January	.99	.99	.91	.82
February	.99	.98	.86	.69
March	.99	.99	.91	.73
April	.99	.98	.81	.30
May	.99	.97	.73	.28
June	.99	.94	.50	.11
July	.96	.86	.45	.11
August	.80	.62	.25	.11
September	.71	.48	.08	.04
October	.96	.86	.54	.18
November	.99	.98	.84	.56
December	.99	.99	.92	.74
December	.99	.99	.92	.74

* Probability shown is the degree of expectation that a specific duration will be exceeded each year, on the average.

Table 39

Deep Water Station DNOD 3

Monthly Total Occurrences of Wave Heights 6 Ft or Greater for Specific Consecutive Days Duration*

Month	Duration			
	1 Day	2 Days	3 Days	4 Days +
January	28	42	28	17
February	33	48	16	17
March	36	51	27	20
April	23	41	24	16
May	37	42	23	14
June	40	44	20	8
July	25	30	13	4
August	17	23	8	3
September	8	9	2	0
October	18	21	5	5
November	27	33	15	13
December	35	47	18	17
(Annual)	327	431	199	137

* 25 years of record, 1950-1974.

Table 40

Deep Water Station DNOD 3

Recurrence Interval (Months) of Wave Heights 6 Ft or Greater for Specific Consecutive Days Duration

Month	Duration 1 Day	2 Days	3 Days	4 Days +
January	0.89	0.60	0.89	1.47
February	0.76	0.52	1.56	1.47
March	0.69	0.49	0.93	1.25
April	1.09	0.61	1.04	1.56
May	0.68	0.60	1.09	1.79
June	0.63	0.57	1.25	3.13
July	1.00	0.83	1.92	6.25
August	1.47	1.09	3.13	8.33
September	3.13	2.78	12.50	--
October	1.39	1.19	5.00	5.00
November	0.93	0.76	1.67	1.92
December	0.71	0.53	1.39	1.47

Table 41

Deep Water Station DNOD 3

Probability of Occurrence of Wave Heights 6 Ft or Greater for Specific Consecutive Days Duration*

Month	Duration			
	1 Day	2 Days	3 Days	4 Days +
January	.68	.82	.68	.50
February	.74	.86	.48	.50
March	.77	.88	.67	.56
April	.61	.81	.62	.48
May	.78	.82	.61	.43
June	.81	.84	.56	.28
July	.64	.71	.41	.15
August	.50	.61	.28	.11
September	.28	.30	.08	--
October	.52	.57	.18	.18
November	.67	.74	.45	.41
December	.76	.86	.52	.50

* Probability shown is the degree of expectation that a specific duration will occur each year, on the average.

Table 42

Deep Water Station DNOD 3

Monthly Total Occurrences of Wave Heights 6 Ft or

Greater for Consecutive Days Duration Exceeding Specific Values*

Month	Duration 1 Day +	2 Days +	3 Days +	4 Days +
January	115	87	45	17
February	114	81	33	17
March	134	98	47	20
April	104	81	40	16
May	116	79	37	14
June	112	72	28	8
July	72	47	17	4
August	51	34	11	3
September	19	11	2	0
October	49	31	10	5
November	88	61	28	13
December	117	82	35	17
(Annual)	1091	764	333	137

* 25 years of record, 1950-1974.

Table 43

Deep Water Station DNOD 3

Recurrence Interval (Days) of Wave Heights 6 Ft or Greater for Consecutive Days Duration Exceeding Specific Values

Month	Duration 1 Day +	2 Days +	3 Days +	4 Days +
January	6.5	8.6	16.7	44.1
February	6.6	9.3	22.7	44.1
March	5.6	7.7	16.0	37.5
April	7.2	9.3	18.8	46.9
May	6.5	9.5	20.3	53.6
June	6.7	10.4	26.8	93.8
July	10.4	16.0	44.1	187.5
August	14.7	22.1	68.2	250.0
September	39.5	68.2	375.0	--
October	15.3	24.2	75.0	150.0
November	8.5	12.3	26.8	57.7
December	6.4	9.1	21.4	44.1

Table 44

Deep Water Station DNOD 3

Probability of Occurrence of Wave Heights 6 Ft or Greater for Consecutive Days Duration Exceeding Specific Values*

Month	Duration			
	1 Day +	2 Days +	3 Days +	4 Days +
January	.99	.98	.84	.50
February	.99	.97	.74	.50
March	.99	.99	.86	.56
April	.99	.97	.81	.48
May	.99	.96	.78	.43
June	.99	.95	.68	.28
July	.95	.86	.50	.15
August	.88	.75	.36	.11
September	.54	.36	.08	--
October	.87	.72	.33	.18
November	.98	.92	.68	.41
December	.99	.97	.76	.50

* Probability shown is the degree of expectation that a specific duration will be exceeded each year, on the average.

Table 45

Deep Water Station DNOD 4

Monthly Total Occurrences of Wave Heights 6 Ft or Greater for Specific Consecutive Days Duration*

Month	Duration			
	1 Day	2 Days	3 Days	4 Days +
January	28	40	19	5
February	30	45	18	5
March	31	41	35	12
April	29	41	28	15
May	39	39	38	22
June	37	46	41	13
July	31	41	35	13
August	48	53	12	7
September	18	18	6	1
October	11	15	10	1
November	32	36	9	4
December	25	37	13	4
(Annual)	359	452	264	102

* 25 years of record, 1950-1974.

Table 46

Deep Water Station DNOD 4

Recurrence Interval (Months) of Wave Heights 6 Ft or Greater for Specific Consecutive Days Duration

Month	Duration			
	1 Day	2 Days	3 Days	4 Days +
January	0.89	0.63	1.32	5.00
February	0.83	0.56	1.39	5.00
March	0.81	0.61	0.71	2.08
April	0.86	0.61	0.89	1.67
May	0.64	0.64	0.66	1.14
June	0.68	0.54	0.61	1.92
July	0.81	0.61	0.71	1.92
August	0.52	0.47	2.08	3.57
September	1.39	1.39	4.17	25.00
October	2.27	1.67	2.50	25.00
November	0.78	0.69	2.78	6.25
December	1.00	0.68	1.92	6.25

Table 47

Deep Water Station DNOD 4

Probability of Occurrence of Wave Heights 6 Ft or Greater for Specific Consecutive Days Duration*

Month	Duration			
	1 Day	2 Days	3 Days	4 Days +
January	.68	.81	.54	.18
February	.71	.84	.52	.18
March	.72	.81	.76	.38
April	.69	.81	.68	.45
May	.80	.80	.79	.59
June	.78	.85	.81	.41
July	.72	.81	.76	.41
August	.86	.89	.38	.25
September	.52	.52	.21	.04
October	.36	.45	.33	.04
November	.73	.77	.30	.15
December	.64	.78	.41	.15

* Probability shown is the degree of expectation that a specific duration will occur each year, on the average.

Table 48

Deep Water Station DNOD 4

Monthly Total Occurrences of Wave Heights 6 Ft or Greater for Consecutive Days Duration Exceeding Specific Values*

Month	Duration			
	1 Day +	2 Days +	3 Days +	4 Days +
January	92	64	24	5
February	98	68	23	5
March	119	88	47	12
April	113	84	43	15
May	138	99	60	22
June	137	100	54	13
July	120	89	48	13
August	120	72	19	7
September	43	25	7	1
October	37	26	11	1
November	81	49	13	4
December	79	54	17	4
(Annual)	1177	818	366	102

* 25 years of record, 1950-1974.

Table 49

Deep Water Station DNOD 4

Recurrence Interval (Days) of Wave Heights 6 Ft or

Greater for Consecutive Days Duration Exceeding Specific Values

Month	Duration			
	1 Day +	2 Days +	3 Days +	4 Days +
January	8.2	11.7	31.3	150.0
February	7.7	11.0	32.6	150.0
March	6.3	8.5	16.0	62.5
April	6.6	8.9	17.4	50.0
May	5.4	7.6	12.5	34.1
June	5.5	7.5	13.9	57.7
July	6.3	8.4	15.6	57.7
August	6.3	10.4	39.5	107.1
September	17.4	30.0	107.1	750.0
October	20.3	28.8	68.2	750.0
November	9.3	15.3	57.7	187.5
December	9.5	13.9	44.1	187.5

Table 50

Deep Water Station DNOD 4

Probability of Occurrence of Wave Heights 6 Ft or Greater for Consecutive Days Duration Exceeding Specific Values*

Month	Duration			
	1 Day +	2 Days +	3 Days +	4 Days +
January	.98	.93	.62	.18
February	.99	.94	.61	.18
March	.99	.98	.86	.38
April	.99	.97	.83	.45
May	.99	.99	.92	.59
June	.99	.99	.89	.41
July	.99	.98	.86	.41
August	.99	.95	.54	.25
September	.83	.64	.25	.04
October	.78	.65	.36	.04
November	.97	.87	.41	.15
December	.96	.89	.50	.15

* Probability shown is the degree of expectation that a specific duration will be exceeded each year, on the average.

Table 51

Deep Water Station DNOD 5

Monthly Total Occurrences of Wave Heights 6 Ft or Greater for Specific Consecutive Days Duration*

Month	Duration			
	1 Day	2 Days	3 Days	4 Days +
January	17	13	12	9
February	36	22	15	10
March	55	48	20	22
April	39	34	15	30
May	16	9	26	44
June	39	20	18	49
July	50	23	18	35
August	41	11	7	30
September	24	5	9	12
October	25	7	8	7
November	26	9	7	8
December	24	17	8	9
(Annual)	392	218	163	265

* 25 years of record, 1950-1974.

Table 52

Deep Water Station DNOD 5

Recurrece Interval (Months) of Wave Heights 6 Ft or Greater for Specific Consecutive Days Duration

Month	Duration			
	1 Day	2 Days	3 Days	4 Days +
January	1.47	1.92	2.08	2.78
February	0.69	1.14	1.67	2.50
March	0.45	0.52	1.25	1.14
April	0.64	0.74	1.67	0.83
May	1.56	2.78	0.96	0.57
June	0.64	1.25	1.39	0.51
July	0.50	1.09	1.39	0.71
August	0.61	2.27	3.57	0.83
September	1.04	5.00	2.78	2.08
October	1.00	3.57	3.13	3.57
November	0.96	2.78	3.57	3.13
December	1.04	1.47	3.13	2.78

Table 53

Deep Water Station DNOD 5

Probability of Occurrence of Wave Heights 6 Ft or Greater for Specific Consecutive Days Duration*

Month	Duration 1 Day	2 Days	3 Days	4 Days +
January	.50	.41	.38	.30
February	.77	.59	.45	.33
March	.90	.86	.56	.59
April	.80	.75	.45	.71
May	.48	.30	.65	.84
June	.80	.56	.52	.87
July	.87	.61	.52	.76
August	.81	.36	.25	.71
September	.62	.18	.30	.38
October	.64	.25	.28	.25
November	.65	.30	.25	.28
December	.62	.50	.28	.30

* Probability shown is the degree of expectation that a specific duration will occur each year, on the average.

Table 54

Deep Water Station DNOD 5

Monthly Total Occurrences of Wave Heights 6 Ft or Greater for Consecutive Days Duration Exceeding Specific Values*

Month	Duration			
	1 Day +	2 Days +	3 Days +	4 Days +
January	51	34	21	9
February	83	47	25	10
March	145	90	42	22
April	118	79	45	30
May	95	79	70	44
June	126	87	67	49
July	126	76	53	35
August	89	48	37	30
September	50	26	21	12
October	47	22	15	7
November	50	24	15	8
December	58	34	17	9
(Annual)	1038	646	428	265

* 25 years of record, 1950-1974.

Table 55

Deep Water Station DNOD 5

Recurrence Interval (Days) of Wave Heights 6 Ft or Greater for Consecutive Days Duration Exceeding Specific Values

Month	Duration			
	1 Day +	2 Days +	3 Days +	4 Days +
January	14.7	22.1	35.7	83.3
February	9.0	16.0	30.0	75.0
March	5.2	8.3	17.9	34.1
April	6.4	9.5	16.7	25.0
May	7.9	9.5	10.7	17.0
June	6.0	8.6	11.2	15.3
July	6.0	9.9	14.2	21.4
August	8.4	15.6	20.3	25.0
September	15.0	28.8	35.7	62.5
October	16.0	34.1	50.0	107.1
November	15.0	31.3	50.0	93.8
December	12.9	22.1	44.1	83.3

Table 56

Deep Water Station DNOD 5

Probability of Occurrence of Wave Heights 6 Ft or Greater for Consecutive Days Duration Exceeding Specific Values*

Month	Duration			
	1 Day +	2 Days +	3 Days +	4 Days +
January	.88	.75	.57	.30
February	.97	.86	.64	.33
March	.99	.98	.82	.59
April	.99	.96	.84	.71
May	.98	.96	.95	.84
June	.99	.98	.94	.87
July	.99	.96	.89	.76
August	.98	.86	.78	.71
September	.87	.65	.57	.38
October	.86	.59	.45	.25
November	.87	.62	.45	.28
December	.91	.75	.50	.30

* Probability shown is the degree of expectation that a specific duration will be exceeded each year, on the average.

Table 57

Deep Water Station DNOD 6

Monthly Total Occurrences of Wave Heights 6 Ft or Greater for Specific Consecutive Days Duration*

Month	Duration 1 Day	2 Days	3 Days	4 Days +
January	31	33	7	5
February	37	40	12	5
March	50	58	29	21
April	46	42	27	31
May	28	35	21	51
June	37	48	22	62
July	39	32	14	38
August	40	34	17	27
September	30	31	18	15
October	24	27	15	7
November	25	27	8	3
December	24	21	9	4
(Annual)	411	428	199	269

* 25 years of record, 1950-1974.

Table 58

Deep Water Station DNOD 6

Recurrence Interval (Months) of Wave Heights 6 Ft or Greater for Specific Consecutive Days Duration

Month	Duration			
	1 Day	2 Days	3 Days	4 Days +
January	0.81	0.76	3.57	5.00
February	0.68	0.63	2.08	5.00
March	0.50	0.43	0.86	1.19
April	0.54	0.60	0.93	0.81
May	0.89	0.71	1.19	0.49
June	0.68	0.52	1.14	0.40
July	0.64	0.78	1.79	0.66
August	0.63	0.74	1.47	0.93
September	0.83	0.81	1.39	1.67
October	1.04	0.93	1.67	3.57
November	1.00	0.93	3.13	8.33
December	1.04	1.19	2.78	6.25

Table 59

Deep Water Station DNOD 6

Probability of Occurrence of Wave Heights 6 Ft or Greater for Specific Consecutive Days Duration*

Month	Duration			
	1 Day	2 Days	3 Days	4 Days +
January	.72	.74	.25	.18
February	.78	.81	.38	.18
March	.87	.91	.69	.57
April	.85	.82	.67	.72
May	.68	.76	.57	.88
June	.78	.86	.59	.92
July	.80	.73	.43	.79
August	.81	.75	.50	.67
September	.71	.72	.52	.45
October	.62	.67	.45	.25
November	.64	.67	.28	.11
December	.62	.57	.30	.15

* Probability shown is the degree of expectation that a specific duration will occur each year, on the average.

Table 60

Deep Water Station DNOD 6

Monthly Total Occurrences of Wave Heights 6 Ft or Greater for Consecutive Days Duration Exceeding Specific Values*

Month	Duration 1 Day +	2 Days +	3 Days +	4 Days +
January	76	45	12	5
February	94	57	17	5
March	158	108	50	21
April	146	100	58	31
May	135	107	72	51
June	169	132	84	62
July	123	84	52	38
August	118	78	44	27
September	94	64	33	15
October	73	49	22	7
November	63	38	11	3
December	58	34	13	4
(Annual)	1307	896	468	269

* 25 years of record, 1950-1974.

Table 61

Deep Water Station DNOD 6

Recurrence Interval (Days) of Wave Heights 6 Ft or Greater for Consecutive Days Duration Exceeding Specific Values

Month	Duration 1 Day +	2 Days +	3 Days +	4 Days +
January	9.9	16.7	62.5	150.0
February	8.0	13.2	44.1	150.0
March	4.7	6.9	15.0	35.7
April	5.1	7.5	12.9	24.2
May	5.6	7.0	10.4	14.7
June	4.4	5.7	8.9	12.1
July	6.1	8.9	14.4	19.7
August	6.4	9.6	17.0	27.8
September	8.0	11.7	22.7	50.0
October	10.3	15.3	34.1	107.1
November	11.9	19.7	68.2	250.0
December	12.9	22.1	57.7	187.5

Table 62

Deep Water Station DNOD 6

Probability of Occurrence of Wave Heights 6 Ft or Greater for Consecutive Days Duration Exceeding Specific Values*

Month	Duration			
	1 Day +	2 Days +	3 Days +	4 Days +
January	.96	.84	.38	.18
February	.98	.91	.50	.18
March	.99	.99	.87	.57
April	.99	.99	.91	.72
May	.99	.99	.95	.88
June	.99	.99	.97	.92
July	.99	.97	.88	.79
August	.99	.96	.84	.67
September	.98	.93	.74	.45
October	.95	.87	.59	.25
November	.93	.79	.36	.11
December	.91	.75	.41	.15

* Probability shown is the degree of expectation that a specific duration will be exceeded each year, on the average.

Table 63

Annual Summary

Days/Year Wind and Wave Conditions Exceed Specified Criteria

Some Potential LNG Terminal Sites, California		Wave Climate Optimized by Use of Model Ship Response Curves (Delft) Sea	North Swell	South Swell	Total	6 ft Accept. Wave Height	Winds Greater Than 25 knots	Combined Down Time*
WES 1	Crescent City	41.2	12.7	3.5	57.4	60.0	58	74.2
WES 2	Point Delgada	34.0	20.0	3.6	57.6	48.0	72	95.6
WES 3	Point Arena	45.7	25.7	4.8	76.2	61.0	71	101.5
WES 4	Point Reyes	8.2	1.2	0.0	9.4	13.0	58	59.2
CCC 1	Davenport	24.0	11.2	4.8	40.0	29.0	48	64.0
WES 5a	Soquel Point	7.7	1.8	0.0	9.5	14.0	47	48.8
WES 5	Moss Landing	7.0	5.5	2.5	15.0	19.0	46	54.0
WES 6	Partington Point	13.4	6.3	3.9	23.6	15.0	44	54.2
CCC 2	San Simeon Point	13.4	6.2	3.9	23.5	15.0	43	53.1
CCC 3	Point Estero	16.0	8.4	4.3	28.7	25.0	42	54.7
CCC 4	Point Buchon	22.9	10.2	4.3	37.4	34.0	41	55.5
CCC 5a	Oso Flaco Lagoon	10.7	8.0	4.3	23.0	23.0	39	51.3
CCC 5	Guadalupe Dunes	18.9	9.8	4.3	33.0	36.0	33	47.1
CCC 6	Point Conception	9.2	1.2	0.0	10.4	8.0	9	10.4
CCC 7	Tajiguas	8.2	1.2	0.0	9.4	6.5	7	9.4
CCC 8	Los Pueblos Ranch	8.6	1.2	0.0	9.8	7.2	6	9.8
CCC 9	Deer Canyon	12.1	1.2	2.6	15.9	11.0	6	15.9
WES 7	Redondo Beach	6.1	1.2	2.3	9.6	15.0	6	9.6
CCC 10	Camp Pendelton	3.2	1.2	3.9	8.3	9.5	5	10.1
WES 8	Oceanside	3.1	1.2	4.4	8.7	8.5	4	9.6
WES 9	Encinitas	4.3	1.6	4.4	10.3	15.5	3	10.3
WES 10	Mission Bay	10.6	1.8	4.4	16.8	39.5	3	16.8
CCC 11	Santa Rosa Island	7.3	4.5	0.0	11.8	29.0	6	11.8
WES 11a	Santa Rosa Island	6.1	0.0	0.0	6.1	16.0	6	6.1
CCC 12	Santa Cruz Island, North	7.4	2.8	0.0	10.2	34.0	6	10.2
CCC 13	Santa Cruz Island, East	2.0	1.2	0.0	3.2	3.5	6	7.2

* Sum of larger of wind or sea + northern swell + southern swell (from the optimized data).

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Hales, Lyndell Z

Preliminary evaluation of wind and wave effects at potential LNG terminal sites, State of California / by Lyndell Z. Hales. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1978.

169, [63] p. : ill. ; 27 cm. (Miscellaneous paper - U. S. Army Engineer Waterways Experiment Station ; H-78-2)

Prepared for California Coastal Commission, San Francisco, Calif.

References: p. 169.

1. Liquified natural gas terminal sites. 2. Water wave height. 3. Water waves. 4. Wave refraction. 5. Wind pressure. I. California. State Coastal Commission. II. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Miscellaneous paper ; H-78-2.

TA7.W34m no.H-78-2